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ENGINEERING AS A PROFESSION.

AN ADDRESS TO THE ALUMNI ASSOCIATION OF THE STEVENS INSTITUTE OF TECHNOLOGY—JUNE 18, 1885.

By WILLIAM KENT, M. E., Stevens '76, President of the Association.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

A RECENT writer on Political Economy says: "The tournament of the world has changed its fields and its weapons. Men no longer strive with lance for a lady's favors. They struggle with matter to change its forms and add to its value. He who can render industry more varied, or more efficient, who can turn any element or gift of nature to novel use, is the winner of the prize." The same writer says further: "Society will not dispense with professional men, although they do not stand so far above the level as in generations ago. We will call upon lawyers when we get into strife over property and they are necessary to the social structure which protects the person. While sickness comes, doctors will maintain their calling. So long as there is a soul that longs for immortality, clergymen will be welcome in home and pulpit. But with expanding industries, with developing science, new professions have gained favor. Commerce has its spheres in which high training and strong intellects are needed and are well rewarded. So has the varied mechanism of this age. In the professions hundreds are starving in this country in the foolish pride of a decayed caste. In the walks of production, wealth invites every man who will bring brains and industry, which will win skill."

It is of one of these new professions, engineering, that I would speak, and I claim for it a rank as a learned profession equal to that of law or medicine, and second only to that of divinity.

Such a claim, for engineering to rank as a learned profession, worthy of all the honors that have been paid to the older professions, may seem to you, who are students or practitioners in that profession, as an unnecessary statement of a truism—one which needs no proof—you already accept it as almost an axiom. But it is not thus accepted by the world at large. In a recent conversation with a lawyer on this subject, he held that it was impossible that engineering could be of equal rank with the three learned professions of the olden time, since all its work tended only to the material advancement of the race; it benefited civilization only by the increase of wealth which it brought; it was of the earth earthy; in fact, a servant of Mammon; while the other professions were on a higher plane, preserving the life and the morals, and dealing with the intellect and with the immortal part of man. So Charles Dudley Warner, in the *North American Re-*

view for Sept., '84, writes of the "Demand of the Industrial Spirit" (of which spirit we must admit that the engineering profession is the hand-maiden) as denying the higher wants of the soul, as "demanding a radical revision of the college curriculum and that the ancient stamp of scholarship shall be put upon industrial and commercial pursuits." He says, "The last demand of the industrial spirit is that all education shall be lowered to its material aims; for lowered it will be, if all distinction is removed in academic honor between an education for the sake of the mind itself and an education dependent on and limited to material and practical aims. The danger in this is no less to science than to literature and philosophy. It is the greatest to all to the tone of modern life."

Such criticisms as these of the modern tendency of educational methods to fit men for the practical duties of life, make it necessary for us to be able to give a reason for our belief that such a tendency is not a degrading one, and that one of the results of such a tendency, that of placing engineering on the high plane of a learned profession, is not a danger to the tone of modern life, but one of its best safeguards, and is a real and important step in the advancement of civilization.

Let us first consider the requirements of the three professions which have hitherto appropriated the distinction "learned," and compare them with the requirements of the profession of engineering. But first we notice that the requirements of the three older professions are not now the same as they formerly were, but are becoming broader and more severe as the general public becomes better educated. In olden times, it might be sufficient for a lawyer to own a few books, to have a knowledge of the forms of law, and to have the ability to browbeat a witness and befog the judge; the doctor needed to be expert with the lance and with the leech, to have a wise expression of countenance like that of the owl, and be faithful in adherence to tradition regardless of the consequence; the minister should be a man of lordly mien, to be able to exercise proper authority and command the respect of his parishioners, and to have the grace of charity and general kindliness of manner, so as to make him always a welcome guest in their homes. In modern times, however, the requirements have greatly expanded. It is necessary for a lawyer, in counsel, to have such intelligence and such honesty, as will enable him to advise a client when to avoid as well as when to seek litigation; in advocacy, to have all the powers given by a thorough knowledge of logic and rhetoric, the quickness of perception, the eloquence and the profound knowledge of the law, which are needed in combat against similar powers arrayed on the other side. In medicine, a doctor must know when to withhold as well as when to give medicine, how to save a leg as well as how to take one off, and he must keep familiar with all the most recent discoveries of medical science, and know how to make proper application of them. In divinity the minister must keep abreast of his flock in intelligence; must be well versed in history, literature and science, as well as theology, to enable him to meet every new argument against his own beliefs which may be drawn from any branch of human knowledge. These three professions now all ask for the most liberal general culture, including not only a classical education, but a knowledge of the universe of learning, of all that is known or to be known of nature and humanity.

Let us compare these requirements with those of an engineer who should rank as a member of a learned profession. He should be a man of broad general culture. No branch of education should be looked on by him with contempt, and his culture should be a broader one than that given by the old college curriculum. The "demand of the industrial spirit" is a noble one. It is for a higher and broader education than that of Oxford and Cambridge. All the culture that the Greek and Latin tongues may give, all that history, literature, music and the fine arts may give must not be slighted. Do the classics give a man stronger reasoning powers? Does literature give him the graces of speech and the power of the pen to mold human thought? Do the fine arts give him the sense of the beautiful? All these are of benefit to the engineer; but to these he must add as more important to his professional success the knowledge of human nature and of finance, gained only in the school of business experience; and

of the higher mathematics, which he must use as easily as a mechanic does his two-foot rule; of the sciences which reveal to us the secrets of nature, geology, mineralogy, physics, chemistry, and their allies; and to all these he must add a sound body with a sound mind, a familiarity with the powers and the limitations of the mechanical trades, and a certain amount of personal manual dexterity.

So vast, indeed, is the field of knowledge which the profession of engineering requires as its foundation, that no one man can be expected to encompass the whole of it. As the jack-of-all-trades is generally master of none, so the engineer who attempts to become educated in all branches of even the ground work of an engineering education, not to speak of the branches of the profession itself, is apt to prove a failure. Hence the necessity not only of specializing the profession of engineering into the branches of military, naval, civil, mechanical, mining, electrical, sanitary, and the like, but also of making a discrimination as to the branches of general education which should be acquired as preliminary to an entrance into the general study of engineering, and of its special branches. Hence the specializing of schools of engineering, Rensselaer devoting itself chiefly to civil engineering, Columbia to mining, Stevens to mechanical engineering.

I may here mention the place which such professional schools should occupy in our general American educational system. Vice-Chancellor McCracken, of the University of the city of New York, said the other day: "The college is a school that teaches something about everything; the university is a collection of schools each of which teaches everything about something." He argues in favor of postponing university work in arts and science until after graduation from college, and says that the only foundation in America that has made its principal business to set up a university faculty in arts and science, the Johns Hopkins University enrolls this year 174 graduate students in arts and science, representing 97 colleges. He does not mention technical schools, such as Stevens, in his address, but I think that if he considered the matter he would advise as I would, that the technical school of mechanical engineering be ranked as one of the schools of the university; a school whose place should be to teach everything about something, and that something mechanical engineering, and not to teach something about everything, which is the function of a college. So also a collegiate education should, if possible, be obtained before entrance into the school of engineering, as the best possible preliminary preparation. And here I would agree with Vice-Chancellor McCracken in his argument against inviting sophomores to become specialists. He says: "It is injustice to a boy of seventeen, and the Harvard sophomore is but seventeen. It encourages him to a premature marriage of himself to some 'ology' or 'ism.' . . . . How can the youth of seventeen, until he has looked over the whole field of learning, decide as to his turn of mind, whether it is not poetic or philosophic, or a mind for invention or for acquisition, for leading or for following, for the study of the world of things or the world of men."

So much for the requirements of the engineering profession as far as education is concerned. Let us now consider its requirements in actual work.

The work of the engineer has been defined as the overcoming of the resistances of nature, and the best engineer is he who effectually overcomes these resistances with the least expenditure of time, labor and money. The successful engineer must love his work for its own sake, and not for its emoluments. He must have the same professional pride that a good lawyer or doctor has, and be ready to sacrifice his money, fame, or even life itself, if duty should demand it. The responsibility thrown upon an engineer is sometimes one whose extent cannot be measured by a money standard. His mistakes may be more serious than those which hurt only the pockets of the lawyer's client, or those which the doctor buries six feet underground. Think of the mistake of the Ashtabula bridge, the engineer of which committed suicide; of the Tay bridge, the disaster to which is said to have broken the heart of its builder. And as to financial responsibility, how many millions of dollars have been lost by engineering mistakes. See the abandoned mines and mills in our

gold and silver districts, the silent blast furnaces and rolling mills built in the wrong locations, the waste of money and of life in the Hudson River tunnel and in the Panama Canal.

No higher trusts are assumed by any other profession than by that of engineering. It behooves that profession, therefore, as much as any other to be sensitive of its honor. Shall a judge be corrupt, or a lawyer defraud his client? No more should an engineer either give or take a bribe, or do aught to bring dishonor on himself, or to demoralize his associates. In manners he should be beyond reproach, but in integrity beyond suspicion.

In its rewards the profession of an engineer is not behind any other. If statistics could be brought to bear I have no doubt that professional engineers could be found, on an average, to be reaping greater financial rewards than the average of doctors, lawyers and ministers of the same number of years in practice. Mr. Roberts, in his "Government Revenue," estimates that of physicians only one-third earn over $2,000 per year, one-fifth earn between $1,000 and $1,500, the next one-fifth will strive for $1,000, and one-fourth will get only $600, $500 or less. Of lawyers he says the annual earnings of less than one-fourth are $2,000 per year, one-tenth in addition receive $1,000 a year. "No calculation can bring the number getting $1,000 a year from their profession to one-half of those on the rolls as in active practice. One-fourth do not earn $500 annually from legal business." I have no doubt that the engineering profession would show a much better record than this if statistics could be obtained.

In the reward of public fame and honor, no profession stands higher than that of the engineer. If a list of the benefactors of mankind since the time of Archimedes should be made, the engineers of the world would be conspicuous in it both in the number of their names and in the grandeur of their achievements.

There is one grand distinction between the professions of law, medicine and divinity, and that of engineering. The former are the professions of conservatism, the latter is the one of progress. The object of the profession of medicine is the conservation of life; that of law, the conservation of morals and the rights of property; that of divinity, the conservation of belief. Engineering, however, is essentially progress. Its history is one of continual advancement. It is like science itself, so far in fact that many of the advancements in civilization greatly credited to science pure and simple, are really the achievements of engineering, an applied science, of which pure science is but the handmaid. In this connection I may quote from Prof. Thurston's paper on the "Mission of Science," and you will note that the word "engineering" might be used wherever he uses the word "science." "A century ago, with the birth of the steam engine, later with the introduction of the product of the printing press into the daily life of the world, with the operation of the electric telegraph and the introduction of the railroad, began the real progress of science, and we are now seeing but the beginning of her awe-inspiring career. She has taught us to drive ten thousand tons across the seas by the might of over 12,000 horse-power engines. She has taught us to send printed messages across the continent; she has shown us how to drive railroad trains faster than bird can fly, yet the mission of science has made but the veriest beginning. It still remains to her to perfect and systematize a thousand new industries, to invent as yet unimagined new arts, to bring the laborer worthy of his hire all that he needs and all that he can desire for his own comfort, and for the care and comfort of his family, to adjust the power of production to that of consumption, and both to the working capacity of the world, so that the now seeming natural conflict between labor and capital shall no longer have even an appearance of existence."

Probably similar thoughts were in my own mind three years ago when writing from the Electrical Exhibition in London, I mentioned the possibilities of future achievements of one branch of engineering, the electrical, I said "These currents of electricity shall furnish power to drive our railway cars, our road vehicles, and our steam boats; shall furnish energy to run our sewing machines, to raise our water, to light and warm our houses and cook our food. They shall separate the ore from the dross, shall

reduce and fuse the ore into metal, and shall gild and refine not only our metals but our whole civilization. And when this is done—when man has subdued unto himself all the forces of nature and forced them to do his work, will he work any fewer hours or less hard? Will he take any more rest, or any more pleasure, or will he be the same over-worked, nervous, ambitious and dyspeptic creature that he is now? Will electricity solve the labor problem? Ah! these are questions apparently beyond the reach of our present philosophy, but they are questions which the future is bringing to us with terrible rapidity. It is wise to look them in the face."

I have thus given you briefly some of my views on the requirements of the engineering profession, of the work it is called upon to do, and of some of its future possibilities. I hope you see as I do, that the profession is not altogether of the earth earthy, that it is not altogether a profession whose end is simply the increase of wealth of a favored few, but that it is a profession charged with as weighty responsibilities and duties to the human race as any other; that it is the profession to which the world must look for nearly all future advances in civilization, whether these come through the enginery of war, civilizing barbarians by the means of modern artillery, through sanitary engineering, at the same time preserving the health and benefiting the morals of mankind, or through inventions which shall so increase the wealth of the human race at large that the primal curse of labor may be to a great extent removed, and the race have more time than it now has for the cultivation of its intellectual, moral and spiritual nature.

WATER METERS (COMPTEURS D'EAU).*

By CH. ANDRE.

Translated for VAN NOSTRAND'S MAGAZINE.

THE FRAZER METER.

There are two forms of this meter: the first introduced in 1872 and the second in 1878.

In the earlier pattern the general form was cylindrical; the smaller sizes being of cast iron and the larger of wrought iron plate. The water coming within the outer casing exerted pressure upon the pistons, of which there were four joined two and two, and single acting. There are two three-port slide valves, working horizontally. The valve for each pair of piston rods regulates the flow for the cylinders of the opposite pair. The registering wheel work is moved by the pistons acting on a ratchet wheel.

In 1878 Mr. Frazer patented his later form of meter, which differs from the first in several particulars. The outlet pipe is supplied with a rubber ball-valve, which serves to mitigate the water hammer shocks on the valves. The pistons turn upon their axes while making the stroke, so as to insure a regular wear on the packing.

There are two double-action pistons in place of the four single-action, thus reducing the length, weight, and price of the machine.

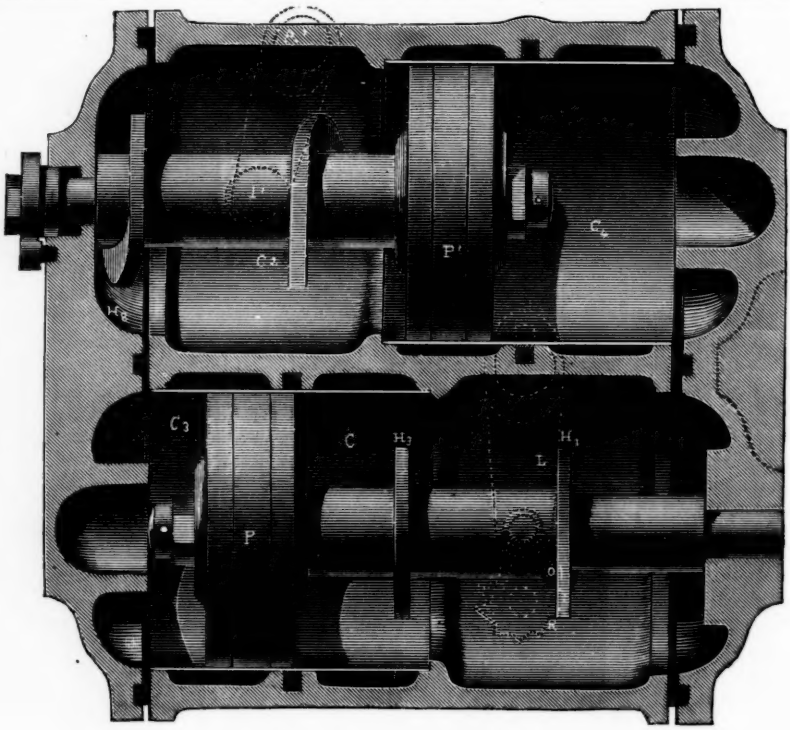
The water enters from above, passes through a strainer which arrests solid particles and also serves to keep the valves in place during transportation.

The valves rotate instead of working back and forward, and are driven by a key and collar on the piston-rod. The adjustment of the parts is such as to admit of examination of the meter at any time.

Furnished with a safety valve, this meter has been applied to the measure of feed-water for boilers.

The durability of the Frazer meter is very satisfactory. The packing of one at the Eastern Railway Station in Paris was recently renewed. It had registered 200,000 cubic meters, and the packing was still water-tight.

*The greater part of M. Andre's paper is devoted to descriptions already given in Mr. Browne's paper. Only the more important of the remaining ones are here given.



THE FRAZER METER (1872 Model).

THE CROWN METER.

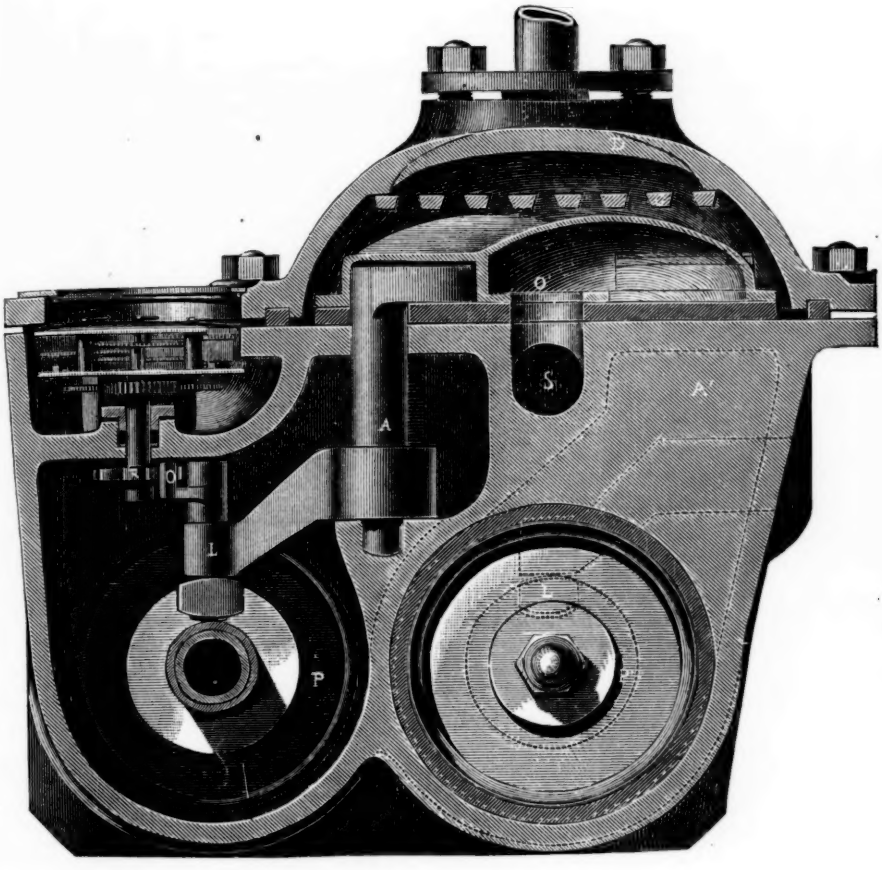
This meter has a rotating piston and is known in France as the Nasch Meter (Compteur Nasch).

The apparatus is enclosed in an iron box. The water enters below and passes through a copper strainer of large surface.

It is composed of four strong pieces, only one of which is movable. One of these pieces is the so called crown. It is substantially a heavy ring with indentations on the concave edge. A pinion rolling on the inside of this crown constitutes the piston. It separates the crown into two water ways. The piston has one tooth less than the crown. The piston has at the center of each face a cavity and a little further out a deep groove. The lower central cavity communicates with the upper groove by oblique conduits through the metal. In like manner the upper central cavity communicates with the lower groove. The piston and the crown are of the same height, and are situated between two fixed discs which perform the office of valves. These discs are perforated with curved conduits opening at their extremities on the side towards the piston. One of these extremities; the one nearest the point where the piston and crown are in contact, communicates with a groove, while the other extremity opens at 90° from this point into the open space between the teeth.

The water enters by a central hole in the lower disc, traverses the piston, is conducted into the upper groove, thence by the curved conduits into the space between the crown and piston and causes the piston to roll.

The water then goes out through the conduits of the lower plate; thence into the lower groove of the piston, passes



THE FRAZER METER (1878 Model).

through the piston and out through its upper central cavity.

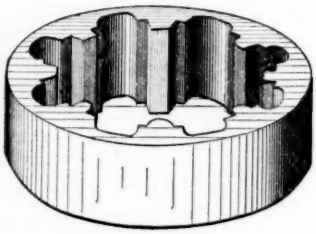
The piston carries on its upper surface a bronze rod, which describes a circle and drives the registering wheels.

The crown meter is especially adapted for measurement of large quantities of water under light pressure. It is also more exact when the delivery is small than are the velocity meters, but is less so than the ordinary piston meters. This naturally follows from the fact that the Crown meter is not furnished with packing and a water-tight piston. Its efficiency depends chiefly upon precision of adjustment and lightness of its piston, which is made of vulcanite. It is put in action by a water pressure of two or three centimeters. Six liters of water per hour will keep one at work.

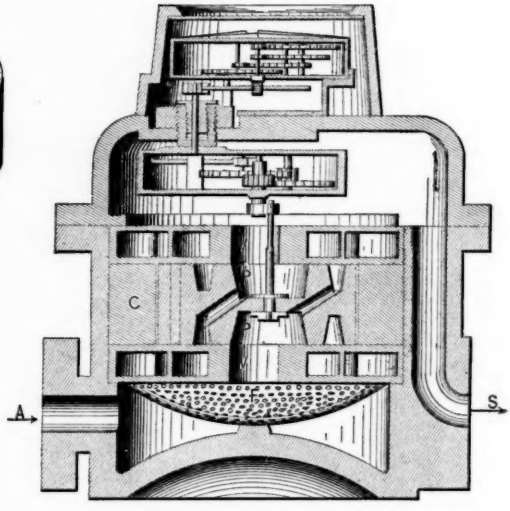
From the experience in French cities, it is concluded that where exactness of measurement is regarded as the first importance, only the piston meters of ordi-

THE CROWN METER.

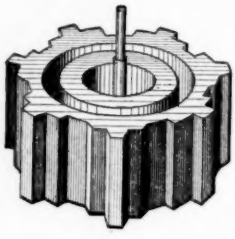
Crown, C.



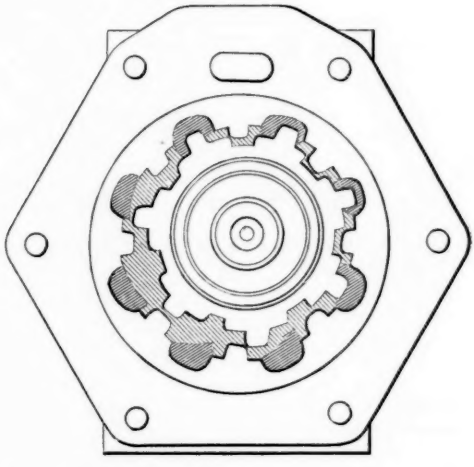
Vertical Section.



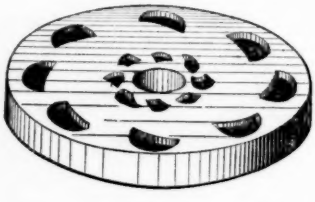
Piston, P.



Plan View.



Valves, V.



nary type are in use. In the provinces the English Siemens meter is most widely employed. Other kinds of meters may be profitably employed in measuring velocities. Piston meters are large and costly, but accurate and durable. The other varieties are small, easy to work, but less exact and more delicate.

The Crown meter occupies a sort of intermediate position between the two classes. Its capacity, its price, and its precision, entitle it to favorable consideration; but where solidity and durability are regarded as essential merits, the piston meters are preferred.

CABLE TRAMWAYS.

By W. N. COLAM.

Paper read before the Society of Engineers.

As is now pretty well known it was in America that continuous wire cables were first adopted for the purposes of street locomotion. The author, however, in addressing English engineers on the subject of cable tramways, thinks he is best considering the wishes of those present by dwelling but cursorily on the birth, history, and construction of the cable system in America; and in devoting a considerable portion of his paper to a description of the Highgate Tramway, which is not only the most recently constructed cable tramway, but the first ever made in Europe. In the case of all inventions which have eventually proved to be of great value, the honors of inventorship have usually been contested. Suffice it to say that the cable system of tramways is of comparatively recent origin, and that the author proposes to leave the question as to who originated it for others to settle. It is doubtful whether the invention in this case would, even at the present time, have been practically worked out had it not been for the fortunate circumstances that a few wealthy men living on the heights of the city of San Francisco had no means of easy excess to their dwellings.

The idea of employing a wire cable for hauling vehicles is, of course, very old, and has been utilized in a variety of ways, but the novelty of cable tramways consists in the secretion of the rope beneath the surface of the road in such a manner as not to interfere with the ordinary traffic, and also in the gripping arrangement, which allows cars of the ordinary type to be used. No two lines on the cable system have as yet been constructed alike, but the principle of working has in all cases been the same, and may be concisely described as follows:

On the cars and under the control of the driver a gripping arrangement is fitted which is extended down through a narrow continuous slot between the rails and into a tube under the surface of the road. Here it is so manipulated by the driver as to close firmly or partially upon, and, when required, to release itself from, an endless wire cable which is kept constantly moving by a stationary engine placed at any convenient spot along or near the line. The cable is supported on small vertical pulleys at suitable intervals on straight portions of the road, but at curves inclined or horizontal, pulleys are substituted according to the nature of the curve. Where very sudden and acute rises occur in the surface of the road (such as at crossings on the San Francisco hills) small inverted pulleys are used to depress the cable and keep it from touching the top of the tube. Such cases, however, are seldom met with in practice.

In the month of August, 1873, a few energetic and skillful men succeeded in overcoming the many objections and apparently almost insurmountable obstacles which invariably attend the introduction of new schemes, and the result of these labors was the construction of the pioneer cable line up Clay Street Hill in San Francisco. This hill is very steep, the severest gradient being as much as 1 in 6; and, like most hills around San Francisco, is leveled where intersecting roads cross, giving the longitudinal section of the road, a step-like appearance. The street length of this line is 2,800 feet, and the altitude risen to in that distance is 307 ft. The first cable used was 3 inches in circumference, and was worked at a speed of 528 ft. per minute for 17½ hours per day, and it lasted over two years. Owing to an agreement made with the local authorities, this line had to be constructed in about two months, consequently it was not built quite so substantially as others since. The line soon proved itself a great financial and mechanical success, and in 1877 extensions were made, but not in the same manner. The total length of cable at present in use on this line is 11,000 ft.

The Sutter Street Tramway Co. closely watched the results of the Clay Street trial, and three years and a-half after the opening of that line they had converted their line to the cable system, as it had (owing to the grades) hitherto for many years been worked unprofitably by horses. This company has now over three miles of double stock, crossing two of the most important thoroughfares in the city. There are four cables employed, all working from one engine-house, three of which work the main line and one a branch line at right angles. The total length of cable in use is 37,736 ft., running at 780 ft. per minute. Near the end of the branch line the cars have to pass round a sharp curve, and no difficulty is found in doing so. One year after the completion of this line the passenger traffic had increased 962,370, and the shares of the company previously offered at £5 sold freely at £12 10s. The construction of this line demonstrated the ease with which ordinary lines can be converted to the cable without seriously interfering with the traffic.

In 1877 the California Street Co. was organized, and opened their line in April, 1878. As the route for this line was very steep, at places being as much as 1 in 5.5, it was decided to build it in a more substantial manner than the previous two, which had wood in their formation. The tube here was solely and wholly a combination of iron and concrete, forming a strong homogeneous mass. The cables adopted were also heavier than before, being as much as four inches in circumference, The total length of double track is 12,650 ft. The engine-house in this case is situated in a valley, and contains two engines, hauling two cables of 8,840 and 17,055 ft. long, at a speed of 537 ft. per minute. Geary, a most central and popular street, was the next route chosen for a cable tramway, which was completed in March, 1880. The grades on this line are comparatively easy, the worst being 1 in 10.3. Here the engine-house was placed about half-way along a double track of 13,200 ft. This line has been very successful and free from accidents, notwithstanding it is crossed at right angles by three horse tramways, one of which also runs over its metals for a considerable distance.

In 1881 the Presidio and Ferry line of 13,000 ft. of double track was constructed. Some of the grades on this line are exceedingly heavy, the worst being 1 in 5.1. There is a curve at the intersection of two streets, the streets from both directions descending towards the curve, around which it was originally arranged for the cars to gravitate; but improved methods have since been introduced, so that either the main cable or an auxiliary one, running at a reduced speed, can be picked up by the cars.

In 1880 the wonderful mechanical and financial success of the San Francisco cable lines excited the attention of tramway companies in other parts of America, and even in the distant English colony of New Zealand. In both places the authorities, having convinced themselves of the value of the system, lost no time in organizing lines, and in August, 1880, the citizens of Dunedin in New Zealand saw the first cable line (out of San Francisco) opened. Roslyn tramway is practically a single line of 3 ft. 6 in. gauge, with turnouts. It is 3,500 ft. long, and the total rise is 500 ft. The steepest gradient is 1 in 7. An interesting feature of this line is an S curve of 215 ft. radius. The success of the Roslyn line induced the Dunedin people to further invest their money in the Mornington Tramway, which was opened in March, 1882. This line is one mile long, and the altitude attained is 430 ft., the worst gradient being 1 in 6.25.

The next city to recognize the advantages of the cable system was Chicago, and on the results obtained there, under so vastly different circumstances and conditions of climate, depended the spread of the system further east, or the limitation of it to milder climates. It may be taken as fortunate that immediately after the completion of the line, in January, 1882, Chicago was visited with heavy falls of snow and severe frost. The cable was at once well tested, and proved to be easily operated, never losing a trip, when all other vehicle traffic was suspended. Again, this winter, the cable system has been uninterrupted, notwithstanding the exceptionally severe weather Chicago has had. The Chicago company had at various times tried all the well-known tramway motors, and they finally reverted to the cable, although the city

is practically a dead level, and the company was doing well, as their $100 shares were quoted at $250. The cables on this line are worked from one engine-house, and are so arranged and actuated that three different maximum speeds are imparted to the cable, suitable for the respective districts through which they pass; thus in one place the cable is always moving at 315 ft. per minute, at another 716, and at another 804. At the end of the main cable line instead of switching the cars to the up line, they are run (at half speed) completely around a square block of buildings which entails four considerable right angle curves. The Chicago company has now a line capable of carrying over 10,000 passengers per hour, and on more than one occasion 100,000 people have ridden on the cars in one day. The annual passenger return before converting was 24 millions, and the first year after 27 millions, with the working expenses considerably reduced.

Market Street, the last line in San Francisco that was converted into the cable system, is by far the most important in that city. For a long time it was thought it would be impracticable to have a cable line in this street, owing to its already very crowded state at certain times of the day. Experience has, however, shown, that out of the eight lines of tramways passing along this street, those worked by the cable are the general favorites, for numerous reasons, amongst others the more uniform speed at which they travel. From 1860 to 1867 this line was worked by steam engines, and by horses from that date to 1883, when the cable was inaugurated. This road has about 10 miles of double track, and several branches worked by 46 heavy and large cars. Five cables of 4 inches circumference traveling at 750 ft. per minute are operated from two distinct engine-houses. The total length of these cables is 90,810 ft., and they weigh over 100 tons.

A noticeable feature in this line is a curve of 80 ft. radius which passes in front of the engine depot, and around which the cars are hauled by an auxiliary cable worked at half the speed of the main line cable.

Lines have been made in Philadelphia, and also one across the Brooklyn Bridge in New York; both, however, have proved failures from an engineering point of view, because in each case the authorities attempted to ignore the potents which cover the construction of good economical cable roads. In Australia the city council of Melbourne has been so satisfied with the report of their engineer, who specially visited and examined the cable lines of America, that they have sanctioned the construction of 27 miles of line in that city, which is now well in hand. The city of Sydney has also granted a company permission to construct a test line of a mile long, with the understanding that considerable extensions will be permitted upon its proving a success.

A cable company has been formed in New York, and the Mayor of that city has granted a concession for the construction of a system 72 miles long, part of which is to be street tramways, and part to run above the street as the present elevated railway does. The decision of the council and mayor has not only been influenced by overwhelming evidence of the behavior of cable tramways, but they have carefully considered the rapid increase of population which is annually being enormously augmented, and they have satisfied themselves that the cable is the only system which will be able to cope with the traffic of a few years hence.

The author has abstained from giving descriptions of the various gripping appliances used on the lines he has alluded to, his object being not to weary the members with described explanations of complicated machinery. He has, however, furnished models which show the principles upon which they have all been made. Having given some information as to what has been done in cable tramways abroad, the author will next proceed to describe the Highgate Hill cable tramway.

It is surprising that notwithstanding the rapid growth and great success of the cable system in America and our colonies during the last eleven years, it was not until May, 1884, that the first cable tramway in Europe was opened by the Lord Mayor of London, on Highgate Hill. To those who had worked hard in introducing the system into this country, it was reassuring to find how soon after

the opening of this line the objections of the local authorities disappeared, and the inhabitants living along the route prepared to vote for further extensions. The power to construct a tramway up the Highgate Hill was obtained by the Steep Grade Tramway and Works Co. during the session of 1882. In the summer of 1883 that company requested the Patent Cable Tramway Corporation (who own all the important patents necessary for constructing such lines) to furnish the designs for and construct their lines on the cable system. On the introduction of anything new into this country the idea introduced has usually to pay heavily for the privilege, and this occasion proved no exception, for the surveyors of the parishes through which this line passed were very zealous in watching the interests of their respective districts, and on so small a line as this their several requirements proved serious and most expensive obstacles to the completion of it.

Highgate Hill is a well-known steep incline rising from the junction of Archway Road, Junction Road, and Holloway Road, in the parish of St. Mary's, Islington; about half way up the ascent it is intersected by two other parishes, viz., Hornsey and St. Pancras, finishing opposite the old historical "Gate House." The summit of this hill and its surroundings is a great holiday resort for Londoners, and on many occasions this line has been severely tested by excessive and sudden rushes of traffic, which would have proved too much for any other system of tramway to have met.

The principle of the system working at Highgate is the same as on all the other cable lines in operation, but the details of construction differ in many respects.

The gauge of this line is 3 ft. 6 in., and it commences at the foot of the hill just where the rails of the North Metropolitan line terminate. The total length is 3,800 ft., of which 3,300 is double track and the rest single. The total height ascended is 239 ft., and the steepest gradient is 1 in 11. The tube is made of good strong concrete, and is connected with the concrete required by the local authorities for supporting the set stones and rail chairs. Tube frames of cast iron weighing 120 lbs. are embedded in the tube, at intervals of 3 ft. 6 in. The object of these frames is to support the Z-shaped steel rolled beams which form the slot in the road for the gripper shank; these beams, which weigh 36 lbs. per yard, are shown bolted to the cast iron frames. The rail adopted weighs 43 lbs. per yard, and is that known as Dugdale's patent. It is supported on cast iron chairs placed opposite each tube frame, to which they are connected by the bolts, firmly securing the gauge true to the slot. The slot is $\frac{3}{8}$ of an inch wide. From the surface of the road to the bottom of the tube is 17 inches, and the width of the tube is $8\frac{1}{2}$ inches.

At intervals of 40 ft. recesses are made in the concrete for receiving the 12 inch cast iron pulleys which support the cable in the tube. The pulleys run loose on spindles screwed into castings, which are held in their places by bolts built into the concrete. The pulleys are kept on the spindles by check nuts, which can be easily taken off whilst the cable is in motion, and the pulley removed and replaced through the hatch in the road. The hatch covers are light cast iron boxes filled with hard wood, and are dropped into cast iron hatches which rest partially on one wall of the concrete tube, and on the bottom flange of the Z beam. The hatch is built in by the paving, and cannot be detected easily in the road. The pulleys are lubricated by Stauffer's patent lubricators screwed into the end of holes bored up the centers of the spindles. At the single portions of the track, where the cable runs in opposite directions through the same tube, the spindles are made longer, and two pulleys placed on them instead of one. These pulleys are inserted where the road curves, and can be removed in the way alluded to before. All the recesses are drained into the sewers.

There are three portions of single track, and at the junction of the double and single tracks two tubes have to verge into one. The slots in following the tubes also converge, and in doing so leave a portion of the road between the slots unsupported. The designing of these points in cable tramways will always require considerable experience only to be obtained by careful observation during the working of such tram-

ways. The triangle formed by the junction of the two slots is a cast steel trough which is rigidly bolted to the Z beams, and supported by a cast-iron frame from beneath. The apex of the triangle is a strong steel spring screwed to the steel trough. This spring is sprung under the top bend, and against the side of the Z beam, where it is supported on a plate bolted to the side of the beam. Thus the slot is always open for the grip shank of the ascending cars. The inside of the steel trough is filled with set stones, thus reducing the metal on the surface of the road to a minimum.

The author will next proceed to describe the three brick pits under the roadway, and the machinery in them for diverting the cable at each end of the line, and at the point where it leaves and return to the tube in passing to and from the driving gear in the engine-room.

1st. The terminal pit at the bottom of the hill. This pit is rectangular in shape, 18 ft. long by 10 ft. wide, and 7 ft. deep from the surface of the road. It is strongly roofed over by rolled iron joists and concrete. It is lighted by gas, and access is obtained to it through a manhole in the road. The machinery inside this pit consists of a narrow cast iron pulley 8 ft. in diameter with V-shaped jaw; it is free to revolve horizontally on a pin vertically let into a cast iron carriage mounted on four wheels. The wheels rest on and traverse the lower inside flanges of two rolled iron joists set at an inclination, between and along which the carriage is free to move backward and forward. A chain is fastened to the lower end of the carriage, and is led over suitable gear to a heavy dead weight, the object of which is to keep the necessary strain upon the cable.

2d. The terminal pit on the top of the hill. This is also a brick pit 18 ft. long and 4 ft. 10 in. wide, and 10 ft. deep from the surface of the road. From the drawing it will be seen that the parts of the cable approaching and returning to and from this pit are quite close together; the cable has, therefore, to be returned to the tube in a different way to that adopted in the lower pit. As the slot passes over a portion of this pit, the roofing is arranged to carry the castings for supporting the slot beams. In this pit are two cast iron pulleys of 8 ft. diameter, one placed immediately in front of the other, one revolves in a vertical plane, whilst the other is canted sufficiently to throw its top out of plumb the same distance as from center to center of cable when passing through the single track.

3d. The pit in front of the engine-house is also of brick, and is so constructed as to be approached from the engine-room. It contains four 8-feet pulleys. The tube slot runs the length of this pit. The slot beams here are bolted to special castings, which are mounted on short cross iron joists resting on longitudinal joists. This arrangement leaves the slot open to the pit beneath. The engine-room is in the basement of the depot, the ground floor of which is used as the car shed.

In selecting the engine for working this line two important points had to be taken into consideration, first, that they should have a most sensitive automatic cut-off valve gear; and second, that they should be powerful enough to do the work of an extension two miles long. The nature of the work on cable tramways varies so much and so quickly that within an incredibly short space of time the engines may be seen both working hard and hauled around by the load. The engines chosen were a pair of high-pressure horizontals, with cylinders 14 by 28 inches, built by Messrs. Grafton & Co., of Cannon Street. They are fitted with Collmann's patent valve gear, which the author considers a very good one for the purpose, and he is thoroughly satisfied with the way these engines have always done their work, the valve gear being so effective that the brake arranged to act on the fly wheel is never called into play. The engines can be disconnected and worked separately when required.

On the engine shaft is fixed a cast iron helical toothed pinion which gears into a larger cast-iron wheel keyed on a countershaft, which also carries the grip pulley. It is this pulley which does all the work of hauling in the cable from the road. The jaws are of a long V shape, and can be adjusted by thinning down or packing up the wood bolted between the segment castings which form the jaws. Although the author consid-

ers this class of pulley gives the cable a rather severe pinch. he is satisfied it releases the cable freely, which is a great point in its favor, especially when used as at Highgate. These pulleys were made by Grant, Ritchie & Co., of Kilmarnock. Immediately in front of the grip pulley, and in line between it and the pulleys, is the arrangement for taking up the slack of the cable, which is something considerable when new or freshly spiced. Changes in the atmosphere will also affect the lengths of the cable. This taking-up arrangement consists of two long rolled joists laid parallel to each other, 18 inches apart and a little above the floor level. On the top flanges of these joists are mounted two 8 feet pulleys, the shaft of the one nearest to the grip pulley turning in journals forming part of a horseshoe shaped casting, which is arranged to be moved either way along the tops of the joists by suitable screw gearing. The front pulley is fixed on a shaft which turns in journals bolted firmly to the flanges of the joists. This latter pulley can be moved forward from time to time and bolted down as before, the operation being repeated as often as the stretching of the cable has exceeded the capability of the sliding pulley to take it up.

The boilers for supplying the engines are those known as the Babcock & Wilcox sectional type, with water tubes, and are worked up to 100 lbs. pressure. This class of boiler is being used very much in the States on cable tramways. For feeding the boilers, a small vertical donkey pump and an exhaust injector have been provided, the latter delivering the water into the boilers at a temperature of about 180° Fahr.

The author having thus far briefly described all the places and machinery through and over which the cable has to work, he now proposes to make one round trip with it, and point out its travel. The speed of the cable is six miles per hour. Starting from the top of the grip pulley, the cable makes one half turn, and passes to the farthest and fixed pulley on the taking-up gear; it there makes one half turn, and comes to the top, and passes over the pulley in the horseshoe casting, where it is again sent down and straight off to the bottom of the left-hand pulley, which directs it up to the large pulley set in line with the tube in the road, whence it is sent on its way down the hill supported on pulleys. On nearing the bottom of the hill the tube is not led straight into the lower pit, but is carried round between the tracks of the first turn-out. The cable leaves the tube at this point, and passes through 10-inch pipes into the lower pit, and on to the horizontal pulley, which directs it into the up-hill tube, in passing through which it is supported in the same manner as in the down-hill tube. Upon reaching the upper terminal pit, the cable passes the first pulley on to the top and over the second, around which it makes a three-quarter turn, and is sent up to the top of the first pulley, which is slightly canted to return it into the tube, close to the up-hill portion of the cable; from it the cable passes down the hill until it reaches the pulleys, where it is deflected downwards and into the engine-room, where it rises gently until it again reaches the grip pulley from which it started. The long length of cable which passes, in sight, through the engine-room, enables any fracture of a wire to be quickly detected, which can be remedied at once or at night as the importance of it demands. The cable used is 8,200 ft. long, and is 3 inches in circumference. It is made up of 114 crucible steel wires of No. 16 wire gauge, and formed into six strands wrapped around a hempen core. The guaranteed tensile strain of this cable was 80 tons to the sectional square inch. The gripper is made of cast steel, and consists of two principal parts, one of which is in the same piece with the lower and movable jaw, and the other with the upper and fixed jaw. The wedge shown, in being forced into or withdrawn from a shoe, raises or lowers the casting holding the lower jaw. The cable is thus seized firmly or slightly or allowed to run through the jaws, as it may be required that the cars should travel full speed, slow, or stand still; and by opening the jaws wide the cable automatically leaves the gripper. The jaws are lined with soft pieces of cast iron, which can be easily and quickly removed and replaced. Two grippers are fitted to each car, one on each end.

The grippers have hold of the cable whilst descending as well as in ascend-

ing the hill, and only release it at the termini and in passing the pulleys in front of the engine-room. At the latter place, as the cars slowly near the pulley, the drivers open their grippers wide, and the cable automatically leaves the jaws. The cars then descend by gravitation along the few feet of deviated track, the object of which is to take the grippers past and clear of the pulleys. On the cars again reaching the straight track, the cable automatically slides into the jaws of the grippers left open to receive it, and the drivers have only to screw up their grippers, when the cars are again carried on at the speed of the cable.

This being the first cable line in England, for obvious reasons it was considered advisable to try more than one form of car, and at Highgate there are now four distinct types of cars working.

1st. An ordinary short wheel-base tramcar with inside and outside seats, but not arranged to carry a gripper.

2d. A dummy or open car which has a gripper each end. This car and the first are worked coupled together, and demonstrates the ease with which the rolling stock of other lines of any system can be attached to and carried on by the cable cars.

3d. A bogie car of an ordinary design with gripping arrangements at each end.

4th. A long bogie car to carry 60 passengers fitted with gripping arrangement each end; this has proved a very remunerative type of car.

All the cars are fitted with two classes of brakes, one of common design which acts on the tires of the wheels; the other a slipper brake which acts vertically on the rails. The latter brake consists of an iron frame firmly secured to the bottom of the car; inside this frame slides a shoe fitted with a long block of hard wood, which the driver, through an arrangement of powerful levers, can quickly force down on the rails, thus utilizing a part or the whole of the dead weight of the cars and passengers. This brake was severely tested by Major-General Hutchinson of the Board of Trade, who tried it on a car which was allowed to gravitate until it acquired a velocity of about 20 miles per hour on a grade of 1 in 11, when the car was brought to a standstill within 30 ft.

The Highgate tramway has now been working most successfully for the past eleven months, during which time it has carried 563,408 passengers, with but two mishaps, which the author is glad to be able to say had nothing whatever to do with the system. Time will not allow now of a full explanation of these unfortunate occurrences, but the author suggests that all interested in the matter should refer to the Board of Trade inspector's report and be guided by it alone.

Engineers will doubtless see at once that the cable system admits of a large increase of traffic, with but small proportionate increase in working expenses. They may, however, be astonished to hear that the Highgate line has carried 100 per cent. more passengers, with an addition to the consumption of coal which was practically nil. It must be interesting to know that every cable tramway constructed and worked up to the present time has paid a dividend after the first year's working. The author cannot now give details of the comparative construction and working costs of cable tramways, but he gives it from his experience that a saving of about 50 per cent. can be generally obtained in a cable tramway of three miles, the cable traveling at 6 miles per hour, and a five minutes' service of cars, allowing also interest at 6 per cent. on cost of construction and equipment as against a horse tramway with an average speed of $4\frac{1}{2}$ miles per hour.

There is little doubt that the time has arrived in England when horse traction on tramways must be superseded by mechanical motors. Therefore, in comparing the relative merits of the known systems able at present to compete, it will be important to remember that there is a large mileage of tramway rails already laid in various parts of the United Kingdom which would be too light to bear the heavier traffic of locomotives depending on adhesion, thus at the out set giving the cable system, even on level roads, an advantage over steam, compressed air, and electricity, an advantage which increases very rapidly with the severity of the grades, until a point is reached when the cable system only can

ascend, and even then work almost as easily as on the level. The latter statement is perhaps at first hard to believe, but its correctness will be apparent when it is remembered that the cable cars in descending hills still retain a hold of the cable, thus utilizing their weight due to gravity in hauling up the ascending cars, a power which on all other systems is thrown away by the application of brakes in descending grades.

The author will conclude by tabulating some of the advantages of cable tram ways, as follows:

1. The steepest grades are as easy to work as levels, the weight of descending cars being utilized to pull up ascending cars.

2. The cars when taking up or setting down passengers are absolutely stationary, the hauling power being practically detached for the time, thus in cases of necessity to avoid collision or danger to life the cars can be brought up instantly.

3. The method of working is noiseless. The stopping and starting of cars is performed so gradually as to be almost imperceptible.

4. Fewer cars are required on the road to do the same work, because the more uniform speed gives a greater mileage per car, and consequently a larger carrying capacity.

5. Sudden increase of traffic can be accommodated to a practically unlimited extent by merely bringing more cars on to the line, the motive power being already provided, and in action.

6. Considerable reduction in wear and tear of the surface of the road as compared with horse haulage, and of the rails as compared with lines on which engines are working; the latter often requiring about 100 per cent. more deadweight to secure adhesion.

7. The traffic is not affected by snow or frost, as evidenced by the following extract from a letter by the Superintendent of the Chicago City Tramway Company: "Though we had at one time frost (snow) two and a-half feet deep, we did not discover any bad effects in our construction or operation."

8. It is the only mechanical motor which does not introduce more weight into the cars than is required for horse tramways, thus saving a renewal of rails when laid lightly for horse traction.

9. It is the only system which prevents cars running away in descending a hill, when all brakes have failed.

10. Its very low cost of working, as compared with other systems, ensures its financial success.

11. It is the only system which is not seriously affected by the proverbial dirty tram rail.

12. Perfect cleanliness of carriage way, a very important sanitary advantage.

13. The extinction, wherever cable traction is introduced, of the barbarous horse system—a cruelty unworthy of humanity and civilization.

TEMPERING OF METALS BY COLD FLOW.—The tempering of metals during the operations of drawing and spinning are well known to all conversant with the details of such work. Cartridge tubes must be annealed between the several operations. Ward's process of making bolts by the cold flow of iron, also requires that such bolts be annealed before the threads are cut; even in flat plates, it is known that the roll temper of thin flat plates of brass or steel is very uniform. It is stated that when Mr. A. H. Emery, of New York, was engaged in making his testing machine for the United States Government, the result of exhaustive experiments upon the subject showed that the temper of steel plates as they are rolled is more uniform than is possible by any later tempering. Some recent experiments on the substitution of low steel for copper and brass in the manufacture of cold-drawn tubing, showed that in the process of drawing the steel became very hard and of increased tensile strength. This new feature is extending the uses to which low steel can be applied. A cannon has been made from such metal by drawing a 6-inch tube with walls ½ inch thick; a 7-inch tube was drawn cold, and when warmed was forced over the first tube; a third tube was fashioned in like manner 8 inches in diameter, and when forced over the other two, completed a 6-inch gun, with walls 1½ inch thick, and cylindrical in outline. It is claimed that such a gun of this dimension, which has been submitted to the United States Ordnance Board for examination, has sustained a water pressure of 75,000 lbs. per square inch; this corresponds to a tensile stress of 100,000 lbs. per square inch of metal. Be it so; admitting that the gun did withstand such a pressure once, it is no measure of the resistance which can be relied on as a safe working pressure of the impact of explosion of powder. Some enthusiastic traveler, on learning that the tensile strength of certain tropical spiders' webs is greater than that of steel wire, has jumped to the conclusion that the ideal cannon would be made by reeling such webs around a thin steel tube.

TEMPERED GLASS.*

By FREDERICK SIEMENS.

From "Iron."

The invention, by M. De la Bastie, of so-called toughened glass, which caused a great sensation at one time, induced the author of this paper to give close attention to the subject, which he proposes to bring before the society on the present occasion. Being a glass manufacturer, there was every reason why he should interest himself in an invention which, entering the lists with great pretensions, claimed not only to revolutionize the glass trade as it then existed, but to supply a new material which should take the place both of glass and metals. The author soon discovered that the De la Bastie process could lay no claim to the advantages to which it pretended, being indeed not a real manufacturing process at all, but rather a somewhat impracticable addition to known methods of glass-making. The wholly finished articles to be toughened had generally to be annealed in the first instance by one or other of the usual means, and thereafter to be heated to such a degree as to render them soft; they were then immersed in a bath of heated oil, or other fluid, capable of being maintained at a temperature of from 350° to 400° C. without evaporation. The toughening of finished articles of glass in this way is not only a very costly addition to the original process of manufacture, but the articles themselves are very liable to have their shapes spoilt and their surfaces injured. But besides these objections, there is another important point to be considered, which is, the liability of toughened glass to burst suddenly into small fragments, either spontaneously or by a sudden shock, like the well-known Prince Rupert's drops, formed by dropping fluid glass into water, whose peculiarity of breaking up into powder has been generally supposed to be due to the sudden cooling of the soft or fluid glass. This theory is, however, only conditionally correct, inasmuch as the cooling influence which acts from the surface inwards is not in proporton to the bulk of the glass, but to its surface, and must always act more quickly on those parts where the surface is large in comparison with the volume. Even the simplest form—a sheet, for instance—cools more quickly at the edges than in the middle, owing to the large surface for cooling which the edges offer. If, however, the cooling is regulated so that at every instant of time the temperature of the article is uniform throughout, no internal tension or strain can arise, and there will consequently be no tendency to crack or break in the way described.

The author, having satisfied himself by a series of experiments of the true cause of the spontaneous fracture of glass, has invented processes of manufacture by means of which glass may be thoroughly toughened, or as he prefers to call it, hardened. The principle upon which the processes depend consists in cooling the glass, not in proportion to its surface, but to its volume or capacity for heat. The method employed will be readily understood by considering a sheet of uniform thickness, which, after having been heated uniformly to a sufficient degree, must be cooled on the surfaces of its two parallel sides only, leaving the edges uncooled. This is done by placing the heated sheet of glass between two cold slabs of suitable material, prepared in a peculiar manner. Uniform cooling of the whole sheet is thus secured, no matter what its shape, because the edges are not subject to the cooling influence caused by the surfaces between which the glass is placed. The plan adopted for various articles varies with their shapes; but it is on the principle of uniform heating and cooling that the author's processes of manufacturing hard glass are based. Of these the two principal are known as press-hardening and casting; but besides these there is a third, theoretically less perfect than the others, viz., semi-hardening or hard-tempering. This, though less important, may be advantageously employed where presses would be unsuitable, and casting

* Paper read before the Society of Arts.

impossible or difficult, as in the case of bottles, lamp chimneys, &c. Press-hardened glass has now been made, with constantly increasing success, for six years, at the author's Dresden glassworks. The output has steadily increased more than 50 per cent. annually, from £600 value in the first year, until last year it amounted to over £7,000, or more than ten times as much. As there is no indication of a diminution in the rate of increase, the author anticipates that the manufacture will assume large proportions. The articles are mainly of plate and sheet glass, either flat or bent into a variety of shapes. Besides plain work, decorated sheets, such as sign-boards with enameled inscriptions, figures, and other ornaments, form an important part of the goods produced; the process, as already stated, is, therefore, one of manufacture (the goods receiving through it their definite shape and decoration), and not simply one of hardening or toughening. The glass is so hard that the diamond will not touch it, and it cannot, therefore, be cut or bent after manufacture; it may, however, be polished, etched, and slightly ground; its strength is at least eight times that of ordinary glass. As only absolutely homogeneous glass of the best quality is suitable for hardening, care must be taken in choosing sheet or plate glass for this purpose, so that it may not be in any way faulty, or contain stones, bubbles, or other imperfections.

The process of manufacture is as follows: The glass is first cut in the ordinary way to the requisite shape and dimensions, and is then exposed to the radiant heat of a peculiarly constructed furnace until quite soft; as soon as it has attained the necessary temperature, it is placed between cold metal plates, to be cooled down with a rapidity which varies with the thickness of the glass, but is in any case very great. The heating and cooling of sheet glass of ordinary thickness last altogether a minute and a-half, a minute being the length of the heating, and half a minute that of the cooling operation. It is a remarkable circumstance that glass may be thus heated and cooled in so short a space of time without either cracking or breaking. This is altogether due in the case of the operation of heating, to the uniform temperature of the furnace, and to the heat being produced entirely by radiation; should these conditions not be fulfilled, the glass would break to a certainty. As regards the success of the cooling operation, this depends upon the uniform temperature of the glass before it is cooled, and upon that of the metal plates between which it is placed whilst being cooled. This uniformity of temperature and the total absence of draught, which would cause irregular cooling, are the conditions under which the whole operation can be carried on with assured success. It is most essential, as regards the good quality of the hardened glass, that the operations of both heating and cooling should be rapidly performed; it is also of paramount importance that the glass should be heated up to as high a degree as is compatible with its being removed from the furnace and placed between the presses, and one of the main difficulties in connection with the process was the arrangement of a proper mode of handling the heated glass, considering that it is almost in the molten state, and as pliable as a piece of cloth. The temperature to which the glass has to be heated is, therefore, far in excess of that of an ordinary annealing kiln, and it is owing to the high temperature employed that the glass can be bent and shaped, as also decorated and enameled, during the process of hardening. In the ordinary process of enameling, the glass can be exposed to a comparatively low temperature only, on account of the tendency to get out of shape. Retorts or muffles are generally used, and the temperature not exceeding that of an annealing kiln, the process of heating up is exceedingly slow, and the enamel to be fixed on the glass has to be of a very soft, easily fusible character; borax enamels are generally used, and even they cannot be properly melted so as to be thoroughly incorporated in the glass. The case is entirely different when glass is enameled by the hardening process; the temperature employed being so much higher, and the heat acting so much more quickly, a more refractory enamel, such as that used for porcelain, becomes available. While in the first case the enamel can be scratched off the glass, and does not resist acids, or even the ac-

tion of the atmosphere, the enamel on hardened glass is as indestructible as the glass itself. From this it will be evident, that the hardening is at the same time the most perfect enameling process, and by far the cheapest, no extra heating operation being required.

It will now be readily understood that press-hardening is essentially a manufacturing process, the same operation which hardens the glass regulating the shape of the article, and fixing upon its surface a highly refractory and consequently superior enamel, admitting of variations of color and design, practically unlimited. It would lead the author too far were he to attempt to enter into all the details of the manufacture of press-hardened glass, which are very numerous indeed, on account of the variety of articles made; these are still on the increase, and there is no saying how long this may continue to be the case. The surface of the metal plates, or moulds used for the presses may be so prepared as to produce more or less cooling effect on the glass as required. If the glass is to be hardened to a very high degree, the metallic surfaces must be of very high heat-conducting power, such as copper, and must be left quite bare; the glass must also be raised to a very high temperature, as it would otherwise crack during cooling. If it is proposed to harden the glass to a lower degree, surfaces of iron are used, this metal not being so good a conductor of heat as copper, whilst the temperature of the glass is also kept lower. By covering the surfaces of the iron presses with wire gauze, their cooling effect may be reduced to any required extent, so that a certain amount of hardening may be produced without rendering it necessary to heat the glass to such a temperature as to make it difficult to handle, or to cause it to stick to the furnace bed. If a still lower degree of hardening is proposed, the faces of the presses may be covered with asbestos paper, or even clay slabs may be employed. It is very essential to the success of the hardening operation, that the heating should be done quickly and by radiation only, otherwise the surface of the goods and their general appearance will be impaired. The bed of the heating furnace must be made very smooth, either by the use of clay, or of sandstone tiles, dusted over with talc powder, and should always be kept in perfectly good order; whenever it becomes uneven, or is otherwise damaged, new tiles are placed on the old bed. Semi-hardened glass is made in the same large radiation furnaces as press-hardened, by means of the hard-tempering process, of which the following is a description: Finished articles, which are of shape to which presses cannot be easily applied, such as bottles, are heated up to such a temperature as will permit of their retaining their form; each one is then placed in a casting of sheet iron, which is so arranged that the heated article shall not touch the inner side of the casing. In order to effect this, the casing is provided with internal projecting ribs, which retain the glass article in position, touching it only at very few points. The casing with the heated article of glass within it is allowed to cool in the open air. Whenever it is a difficult matter to handle the heated glass, instead of placing it hot into the casing, the casing with the glass inside it is inserted in the heating furnace for the requisite time, and then allowed to cool as before described. The hard-tempering process is only applicable to articles of nearly uniform thickness throughout; bottles with thick bottoms, for instance, are not fit to undergo the treatment, as they would be apt to crack both during heating and cooling. The strength of semi-hardened is about three times that of ordinary glass, and it is not affected to the same degree as the latter by change of temperature. The process finds much favor, as the constantly increasing orders sufficiently prove. To secure success, a properly constructed heating furnace is of the utmost importance as regards both processes. As already explained, it is necessary that there should be no draught within the furnace, that the heat should be uniform, and that the flame should not act directly upon the sheets or other articles of glass, which would be thus tarnished, and liable to break whilst being heated, or on cooling, if not heated uniformly. The furnace employed is the regenerative gas furnace, heated by radiation, which the author has lately introduced, with great advantage, for many industrial purposes, and fully described

in a paper he read before the Iron and Steel Institute, in September last.

The third and last process to be described, which the author considers the most valuable of the three, is a peculiar mode of casting hard glass. This has not yet been introduced on a manufacturing scale, but the experimental castings produced have turned out to be quite satisfactory in every way. They consist of floor plates, grindstones, pulleys, tramway sleepers, and various ornamental work. The author thinks that castings might be produced with advantage for many other purposes, especially in connection with the building trades; but this can only be ascertained after works are established, which are now in course of construction, for the regular supply of goods manufactured by this process, as already the case with the previously described processes. Glass may be cast in this way into a variety of forms, which it would be impossible to produce with ordinary glass, owing to the liability of the latter to crack whilst cooling; it has, moreover, at least four times the strength of common glass, and can be made much more cheaply. It is manufactured in the following manner: Glass, melted in a tank furnace, such as described at the meeting of the Iron and Steel Institute, already referred to, is tapped into molds, as with iron castings. The process thus far resembles that carried on in an iron-foundry, but differs from it, inasmuch as a special material is used in place of sand, and that the mold and the glass inside it are heated and cooled together. The material or mixture to be used in place of sand must be selected so as to have, as nearly as possible, the same conductivity and capacity for heat as glass. In such a case, the glass and mold forming, as it were, one homogeneous body, the glass will cool without crackling, even if the cooling process is comparatively quick, which is quite necessary if hard glass is to be produced. Glass cast in this way may have almost any variety of form and inequality of thickness, in the last respect this process differing entirely from those previously described, in which only glass of uniform thickness can be dealt with. If care be taken that the surface of the glass does not approach the outer casing of the mold, it does not much matter how the cooling is effected. The great point is that the mold and glass should be brought to a uniformly high temperature, which should be rather above that at which press-hardened glass is made. When fully heated, the mold is taken from the furnace and allowed to cool in the open air, which generally acts quickly enough to produce a good hardening effect upon the glass within. When cold, the mold is opened and the glass removed.

It will be readily understood, from the description given, that the three processes differ so materially from one another that hardly any resemblance remains to show that they are merely different ways of treating differently-shaped articles, in carrying out the principle of keeping the whole body of the glass at a uniform temperature during the operations of heating and cooling. The De la Bastie process, as well as the ordinary tempering processes employed, fail in not being founded on the principle set forth; glass toughened by the De la Bastie process being cooled in a fluid bath, and ordinary glass in kilns, the cooling action is most active on the portions offering the largest surfaces to the cooling influence, and hence in the one case there is a strong tension or strain in the molecules, which causes them to break up spontaneously; and, in the other case, to counteract that tendency, it is necessary that the glass should be cooled very slowly. In all cooling operations the principle developed in the paper ought to be the ideal aimed at, and the author is convinced that ultimately every kind of glass will be more or less hardened in the cooling process. There is no reason why this should be done quickly; it may be done slowly, so as to allow of the glass being cut and ground while still possessing increased resisting power, and having less tendency to break under the influence of change of temperature. In the future, hardened glass will bear the same relation to ordinary glass that steel now bears to iron. It will, of course, be a long time before this is brought about, just as it has taken a long time to develop the use of steel to such an extent as almost to have replaced iron in the market. As a proof of the extent to which the production of hardened articles of glass has been already developed, the author has placed

some samples of hardened glass on the table. The members of the Society of Arts will thus be in a position to judge for themselves as to the comparative value of this glass, as well as of its strength and immunity from temperature influences. In the collection is included samples of military water bottles, of which more than 10,000 have already been supplied, mostly to volunteer regiments in this country, and glass similar to that used for fitting up the chart-room on board the Inflexible, which was ordered after a report of trials made on board of the Glatton, where the tempered glass withstood the concussion of the firing of heavy guns. From the steady progress in the past there is every reason to believe that in future the hardening processes described in this paper will be applied to all manufactures of glass of an important character.

Several experiments were made at the conclusion of the paper, to show the strength of the tempered glass, pieces of ordinary sheet glass and of the tempered glass being placed on four corks, and a cricket ball dropped upon them from various heights. The ordinary glass broke with a fall of about 2 feet, whilst in some cases the tempered glass did not break except with a blow from a height of 5 feet 4 inches.

Discussion.

Mr. E. A. Cowper said great thanks were due to Mr. Siemens for bringing forward this new manufacture in a practical form; but it was not a new thing, nor a small matter, seeing that the business had risen to £7,000 a year in six years. Several of the drinking bottles he had seen for some years past, and they were very much liked, because they were clean: tea could be put in them one day, and beer another. The question of cutting with a diamond was a very curious one. You could scratch the surface of some of these sheets, but you could not cut it; it would not split through as common glass did. Probably that was due to common glass being in a state of tension, which, when relieved by a scratch, caused the glass to fly right through; so that even plate glass, half an inch thick, would succumb to the slightest scratch of a diamond one-hundredth of an inch deep. With this glass you could not do that. The castings would be an important new manufacture. The tempering was not so thoroughly carried out in this case as in the hardening of glass in other forms, but it was sufficiently hard to serve as sleepers for tramways and railway chairs for electric railways. He thought, also, architects would welcome this as a means of obtaining articles of various tints, whereas they at present had to search for different stones. By this process they could obtain them, to any extent, in various tints, and in any form, by casting. Something of the same sort was attempted some years ago by Mr. Attwood, who used basalt, which was cast at Chance's factory in Birmingham. He made some heavy castings for mantelpieces, and so on, but it was a complete failure, as there was no means of hardening or probably annealing them. Some flew to pieces. One of the defects of the De la Bastie process was that the articles sometimes suddenly burst into little bits, the reason of which no doubt was that, being dipped into a liquid, one part necessarily got cool before another. If you wish to set up various strains by producing various temperatures at the same instant of time, there you had the process in perfection, for it was impossible to dip a glass article even into oil at a high temperature without chilling it in such a way as to produce varying strains. The cooling surfaces Mr. Siemens used were, first, a large plate of iron, on which the glass was quickly laid, and then the top plate came suddenly down upon it, and it was squeezed perfectly flat, so that every part was in contact with the iron. If it were merely laid on a sheet of iron the glass might cockle a little, and the proper effect would not be produced. Various experiments would be necessary to give the exact comparative strength, and he should have liked particularly to see experiments on the actual tension by pieces being put into an hydraulic press and pulled apart. It was evident this product was very much liked in Germany, and some day, no doubt, it would be equally popular in England.

Mr. Ludwig Mond said he had been much struck by the difficulties which Mr. Siemens had so successfully overcome in this manufacture. As he and his lamented brother had been the originators

of processes which had wrought such great changes in our art industries, it was quite certain that, in undertaking this question, Mr. Frederick Siemens would solve it successfully, although it had baffled the efforts of others. He regretted that Mr. Siemens had not given some description of the furnace he used. As a chemist, he might remark that, when the question of glass turned up, it was found to be now practically the same substance chemically as that it was at the time of the Phœnicians. He certainly thought it would repay the chemist to attack the question from the chemical point of view, and see what could be done, not by mechanical processes—by heating and cooling—but by attempting to produce new chemical compounds which should possess the qualities desired.

Mr. J. Head then drew attention to the various specimens exhibited, particularly to the ornamental glass, which was ornamented and tempered at the same time. Another useful application of this process was in enameled plates with names and addresses for streets, &c., which might be made very strong and cheap. A sample of this kind was not on the table, but one was being made, bearing the name and address of the society, which would be presented to it. Amongst the other specimens he drew particular attention to a large casting in the shape of a tuning fork, which was very resonant on being struck.

Mr. Siemens remarked that that shape could not be produced at all in ordinary glass in a mold, as it would be sure to crack. It could only be produced by pouring it into a mold formed of material having the same heat-conducting power.

Mr. R. W. Wallace referred to some experiments he had tried some months ago with the De la Bastie process, with the result that in almost every instance, with a less glow than had been shown tonight, the object had suddenly cracked, and the appearance of the fractured glass was altogether different; it broke into a great many pieces, and when you examined the fracture, it was evident that the cooling was done in an altogether different manner. The structure seemed to be quite amorphous, and it broke up into a condition like sand. He had had some experience of these drinking bottles, for two years ago they were served out to the Inns of Court Volunteers, who took them to Brighton on one occasion and to Portsmouth on another. During the whole time he only saw one broken, although they were subject to very rough usage, such as knocking the butt end of rifles against them, and throwing them about the floors of the barrack rooms, every effort being made by the volunteers to try and show that they were no better than those they had had before. In the end, however, they gave unbounded satisfaction to every one who used them. He hoped to hear something of the applicability of this glass for chemical experiments. Some years ago he tried some experiments with retorts toughened by the De la Bastie process, but they were not successful. Glass could be used in the manufacture of sulphuric acid, but only in one process; you could not manufacture the acid continuously. If you brought the heat up gradually and allowed it to cool gradually, you could concentrate sulphuric acid in a retort; but if you tried to do it continuously the retort cracked immediately. With a De la Bastie glass retort he got a slightly better result than with ordinary glass, but not a successful one, and he should like to hear whether any attempts had been made in that direction with this glass. Of course he could see there would be a difficulty in getting the annealing surface on the inside of the retort, but perhaps that might be met by making the retort wider at the top. All who were interested in these matters owed a great deal to the firm of Siemens for the energy and skill with which they had attacked these problems. Some day, perhaps, they might have bells made of glass.

Mr. Perry F. Nursey said, about ten years ago toughened glass by the De la Bastie process was brought under his special notice. He was requested by some friends to investigate and report upon it, and for that purpose he went to the factory near Paris and saw the process, which was heating the glass and plunging it immediately into hot oil. It was singular that long before De la Bastie worked out that process, he attempted the very means which Mr. Siemens had adopted, but without success,

for he attempted pressure, adopting the idea from Sir Joseph Whitworth's process. He had had the honor of reading a paper in that room on the subject, and perhaps some were present who witnessed the experiments on that occasion. To his mind, those shown that evening did not compare with those which he then showed. He might say that when he visited M. De la Bastie's factory, he tried an experiment with a number of champagne tumblers which were placed edgeways on a shelf. He fired at them with a saloon rifle at twelve paces; several times he knocked them off their perch, and one obstinate one he knocked off twelve times in succession, and only broke it at the thirteenth shot. It was a very severe test. In order to ascertain what the real strength of the material was, he carried out a series of tests in conjunction with Mr. Kirkaldy, and their report was made on May 18, 1875. There were ten pieces of tempered and ten of untempered glass of various lengths, 12 to 15 inches, and 4 inches broad, and all the same thickness, about 0.265 inch. They were placed on supports giving a bearing of 5 inches, a block of wrought iron being cut out to make a pan beneath. Under each edge were laid strips of indiarubber, and on the top was placed another piece of rubber, and on that pressure was brought from a knife edge, in some instances by a gradually increasing weight; in others the strips were placed in a testing machine, and the knife edge brought on them horizontally. The mean result was that the ordinary glass stood 206.2 lbs.; the tempered glass 828.1. Mr. Cowper had referred to the desirability of having tensile tests made, and he hoped he would carry that wish out, but he believed it would puzzle his ingenuity, as it did his own and Mr. Kirkaldy's, for they could not get the glass to be held by any known means; they could not get a bite on the glass. With regard to the tests made by Mr. Wallace, he did not think the material could have been properly tempered. In some instances, glass articles made by English manufacturers did not come out so well as those made by De la Bastie himself. Having quoted from the report in the society's *Journal* the account of his own experiments, he added that on that occasion one gentleman dropped a plate of the glass on an iron hearth at a distance of from 1 foot up to 5 feet without breaking it. He did not deny that Mr. Siemens had improved on this process as far as ornamentation went, but he did not think De la Bastie had attempted anything of that kind, though his glass could be ground by the sand-glass process. He had some tumblers at home, beautifully engraved with his monogram, which had been in use for ten years. The process had now dropped into abeyance, but recently he understood it was being brought out by another company.

Professor Grylls Adams, F. R. S., said he was very much interested in seeing experiments with regard to the breaking strain of glass, and one could judge at once by comparison of the heights the amount of energy actually spent on the glass. In one case dropping a ball less than 2 feet broke the ordinary glass, whilst it went up to 5.4 to break the tempered glass, and taking the comparison between the two, it would give an estimate of the actual energy spent on the glass. Of course, it was of great importance, in performing such experiments, that they should be exactly under the same conditions, and these could only be taken as a rough proof that one was much stronger than the other, and it was hard to judge what the actual strength would be. He was much interested in the strength of glass, principally from an electric point of view.

Mr. D. Chadwick said he was disappointed at not seeing any toughened glass experimented on, to show the relative strength of that and Mr. Siemens'. He could endorse all that Mr. Nursey had said about the De la Bastie glass, which he had experimented on over and over again, and he felt certain it would stand greater violence than that which had been shown that evening. Mr. Cowper had spoken of the way in which that glass was cooled, which caused it sometimes to explode spontaneously, and no doubt ten years ago that did occur, but as now made, such a thing was so rare that practically it did not apply at all.

Mr. McLaughlan asked if any attempts had been made to make this glass into

tubes, and also what was the cost as compared with other materials.

Mr. R. M. Lawes also asked the relative cost of manufacture by this process. The other day, on purchasing some toughened glass, he found it was nearly double the price of ordinary glass, if this were as dear as that, it would not be likely to come into general use.

Mr. J. Stone said he remembered attending the meeting when the De la Bastie glass was introduced, and it was then stated that slabs of glass for roofing purposes, if they cracked at all, cracked immediately into thousands of pieces, which of course was dangerous for workmen, but he noticed that this glass did not break at all in that manner.

Mr. Frederick Siemens said his process and that of De la Bastie could scarcely be compared, because the latter was merely a toughening process, whilst his was one of manufacture, by means of which he shaped and hardened the glass in a single operation, either by means of presses or casting into moulds, and in a new manner. The De la Bastie process was only an additional operation, applied after the article was finished to toughen it; but even for that purpose it was wrong, inasmuch as the cooling influence acted in proportion to the surface, whereas it ought to act in proportion to the bulk of the glass. Those parts which exposed much surface to the cooling influence, cooled more quickly than those of less surface, and, consequently, there would be unequal cooling which should be avoided. At each unit of time the whole article should be at one temperature, and that could only be effected by regulating its temperature according to its capacity for heat. If one part was cooled more quickly than another, there was a strain which could never be removed. For that reason the process of cooling in a bath was wrong; whilst the slow cooling applied to ornamental glass. was expensive. By the ordinary mode many articles which he had shown could not be produced at all, even if cooled ever so slowly, for they would have very little strength, and the least accident would cause them to break. Toughened glass was apt to break spontaneously, owing to the tension set up during the process of toughening; generally speaking, if it did not break very soon, it would last a long time; but its liability to break was the reason it was expensive. He had omitted many points of detail from the paper for the sake of brevity, but he described three different processes, in each of which there were many peculiarities. He had already described the construction of the furnace at the Iron and Steel Institute, and a great deal depended upon it, not only as regarded the success, but also the economy of the operation. [Mr. Siemens drew a rough sketch on the board to show the kind of furnace he used, in which the flame was shown to pass over the top of the furnace without touching the articles, radiating the heat down upon them.] On the bed of the furnace were tiles on which the articles were placed. The flame was about three feet from the glass, which caused a uniform heat, and prevented injury to the articles themselves and to the bed of the furnace. The articles were removed with wooden shovels, impregnated with water glass so as to render them incombustible, and they were then placed upon a cool metal plate, upon which another was pressed down. He had only brought forward manufactured articles such as were sent out to be used; the bottles would stand four times the ordinary wear and tear, and the sheets eight to ten times. He arrived at this conclusion from the circumstance that the breakages of the street lamps of Dresden and Berlin were now only about one-tenth what they used to be, and only cost one-tenth for repairs. He could have prepared glass which would stand very much more strain than that tested; he might have selected pieces which had stood the test already; but those shown had been taken quite at random. Sometimes a piece would break at five feet, though it had already stood the test at ten feet, or it might be dropped on the ground several times without injury, and eventually break, the difference of result depending entirely upon how the glass was struck. Bottles and hollow articles were the most difficult to harden; the sheets and hard castings were the most perfect, but hollow articles could not be made very well in the way in which those were made. Pipes might be cast, moulding them somewhat as iron pipes were; but it would require a little ingenuity. The

strength of an article could be increased by heating it to a higher temperature, and cooling it more rapidly, but there was a certain limit when the manufacture became unsafe; and for commercial purposes it was necessary to avoid losses through breakages, which would make the articles expensive. With regard to the price, it differed very much, some articles were very cheap indeed; it did not cost more to glaze a street lamp with tempered than with ordinary glass, but then the glass was supplied in sheets ready cut to the exact size, and the expense of the glazier's time in cutting the glass, and the loss thereby occasioned, was saved; but it could only be introduced for that purpose as corporations of towns came to have lamps or window panes of a uniform size. Decorative glass was produced more cheaply by this process, because the ordinary mode of decorating was by an additional process which was very expensive, the glass having to be heated in a muffle slowly, besides which the heat used to burn in the designs and inscriptions was not high enough to fix them well.

There was hardly any limit to the designs which could be produced in this way; anything that could be done on porcelain could be done on this glass, and it could be done more cheaply. It would be useful for signboards of houses or shops, but there must be an establishment near the place where the glass is to be used, as it would not pay to send single sheets from Dresden to London. With regard to the hard castings, he had not had so much experience, because they had not yet regular manufacturing establishments, and had hitherto only manufactured them experimentally, whereas real knowledge on such subjects was only to be attained by practical working. The hard-casting process, although it had not yet been brought out commercially, was, in his opinion, one of the utmost importance, as it was an entirely new process, by means of which glass might be made in any shape which could be molded, and of a strength which could not otherwise be produced. The material employed for molding was certainly dearer than the molding sand used for castings of iron. This was due to the circumstance that it must not only be suitable for molding, but had to be, when molded, of the same conductivity and specific heat as glass. He was still making experiments, so as to obtain the most suitable material for this purpose, but had found various mixtures of powdered porcelain and glass pots, metal turnings and filings, and such minerals as heavy spar and magnetic iron ore, to be suitable when mixed in certain proportions. On the whole, these materials were not dear, and, as regarded the labor and expense of molding, it would probably be about the same for castings of glass as of iron. As a manufacturer, he looked upon cost as a most important matter for consideration, as, however good a thing might be, it was of no value commercially unless cheap enough to find buyers. As regarded the hard-cast glass, he could produce a hundredweight of castings for about 5s. 6d., which should be cheap enough for any purpose for which it was proposed to be used. He was now erecting a factory which would be at work in a couple of months' time, and later on he should be pleased to give the society further information on the subject. He felt quite satisfied that orders would come in, for his hard-glass castings supplied a want which was felt on all sides. Glass was not liable to oxidation or to wear away, and as soon as it could be depended upon for strength, and could be made cheaply, it would be applied for purposes for which metals, stone and porcelain had hitherto been used. If a factory were established in London, he believed a great trade would spring up.

Mr. Wallace asked if slag could be utilized.

Mr. Siemens said it depended largely on what the slag consisted of, for this varied very much. The only advantage would be in running it direct from the blast furnace, so that it need not be remelted, whilst there was the disadvantage that it contained no alkali.

Mr. Head remarked that, considering these articles were only one-third the density of iron, and cost 5s. per cwt., they would be really very much cheaper.

In reply to the chairman (Professor James Dewar, F. R. S.)—

Mr. Siemens said, one physical property in which this glass was different from other glass was that it stood changes of temperature better. It might be a little

more elastic, but it was not tough, only hard.

The chairman said that the specimens of the De la Bastie glass which he had seen in the field of the polariscope at once revealed enormous strains; he should like to know if this glass showed anything of the same kind.

Mr. Siemens said it showed something, but not much.

Professor Adams said he should like to have the opportunity of testing this glass in that way. There was no question that the toughened glass was very much under strain, because the usual figures of unannealed glass, depending on the shape of the glass, were very clearly marked.

Mr. Siemens said if they could ever come to such perfection as to cool actually in the ideal way, that appearance would be taken away. Some pieces showed it more than others.

The chairman said this was a most interesting communication in every respect, and fully worthy of the Siemens family. They always found in the papers of Mr. Siemens and his brother that they began on some perfectly definite basis to achieve a particular result. Any one attacking this problem for the first time would hardly have thought of trying industrially to eliminate from any given surface of glass a quantity of heat which should be perfectly uniform and definite; and that, achieving that, you might do it at as rapid a rate as you could attain. In fact, he understood that the more rapid the more successful it would be, provided it was uniform. Here the scientific problem was to withdraw a certain number of units of heat quite uniformly, and at a uniform rate, from each side of a piece of glass, so that the old idea that the only way to reach uniformity in a plastic solid of complex nature like silicate, by slow cooling, and allowing the molecules to gradually attain their normal state of want of strain, might be achieved practically instantaneously, if done in a proper way. It was really a most remarkable result, not only in itself, but from the applications it was likely to open up in the future. Nothing succeeded like success, and the figures given as to the demand for this manufacture were sufficient proofs of its usefulness. He concluded by proposing a cordial vote of thanks to Mr. Siemens for his admirable paper, which was carried unanimously.

ON THE ANTISEPTIC TREATMENT OF TIMBER.

By SAMUEL BAGSTER BOULTON, Assoc. Inst. C. E.

From Papers of the Institution of Civil Engineers.

II.

DISCUSSION.

Sir Joseph Bazalgette, C. B., President, said the subject of the paper was an exceedingly practical one. Timber, in the majority of countries, was the most available material for constructive and engineering purposes, and in some countries it was almost the only material which could be used. The great defect in its use was its want of durability. Anything, therefore, which could remedy that defect, and give durability to the timber, must be a subject of great interest to the engineer. The author in the paper had given the result of thirty-four years' experience, together with his researches into what had been done ages before, and the whole had been placed before the members in a manner showing that he had devoted very great ability and attention to the subject. Although the author was commercially engaged in that branch of engineering, he was sure the members would feel that the paper had risen considerably above the commercial element, and had clearly shown that science could be, and had been, brought to bear on industrial art, so as to improve it and make it of great value.

Mr. Boulton remarked that the subject of his paper was one which had occupied his attention for many years. He hoped he had clearly explained the analytical investigations by which he had sought for

some clue to what was a rather complex labyrinth, namely, the kind of substance which was the best to put into timber for its preservation. He had employed many of those substances, and the conclusion at which he had arrived was that, supposing the substance to be a good antiseptic, whether, as in former times, corrosive sublimate, sulphate of copper, or chloride of zinc were used, or whether creosote oils, there was always a close connection between the durable results of the antiseptic and the immunity of that antiseptic from volatility in the air or solubility in water. Timber must be exposed to air for engineering purposes, and also to water; in some cases in marine work, it was in the water altogether, and therefore, the antiseptic ought not to be liable to evaporation or to being washed out by the action of the water. He was not there to advocate the use of the creosote of one district more than another, because, commercially speaking, that was a matter that did not affect him. He thought that all honest creosotes made from coal-tar in England were useful for the purpose of preparing timber; but he thought that some of them were more useful than others, because they were more durable. If, therefore, engineers would take the trouble to follow out his idea, and study the different constituents of the creosote oils, remembering which of them were the most durable and the least soluble, that would give a clue to the formation of fresh specifications for the preparation of timber. He did not think that the present specifications were satisfactory in all respects. Plate 6 represented the products derived from Newcastle coal, such as was ordinarily carbonized in London gasworks. There was, as had been explained in the paper, a different series of products from the Midland coals ordinarily carbonized in other parts of the country. Taking the same coals—those carbonized in the gasworks—and subjecting them by carbonization to a lower temperature, another class of products would be obtained as had been pointed out by Dr. Armstrong in a recent discussion. It was as well that engineers should bear that in mind, as they were now witnessing an inauguration of a new series of industries, namely, the partial carbonization of coal in coke ovens, partly for the purpose of getting the products direct, instead of through the gasworks. Those other products might be valuable, but they were not the same as far as the preparation of timber was concerned, for they were lighter and more volatile. He had taken the trouble to get some truckloads of different coals used ordinarily by the London gas companies; he had carbonized them on a large scale at lower temperatures, and had found that he obtained thinner and lighter oils with a specific gravity of from 930 to 1,030, instead of from 1,045 to 1,060, and he had a different class of products altogether.

Dr. C. Meymott Tidy said it was twenty years ago when he commenced working with creosote, and he was bound to admit that since that time his views had undergone considerable changes; but he supposed there was no great harm in that, for the views of engineers, politicians, and even of theologians, were constantly shifting. The process of creosoting was of a threefold nature. First, there was the physiological action of rendering the wood a poison, so that animals could not or would not attack it; secondly, there was a chemical action, consisting chiefly in the coalgulation of the albumen; and thirdly, there was what he held to be by far the most important action of the three, namely, the simple mechanical action. The process of creosoting was practically a choking up of the pores of the wood so that neither air, moisture nor life could get inside. He well remembered the late Dr. Letheby drawing up his original specification. No doubt he was very strong in his belief of the enormous value of carbolic acid; indeed, he regarded it, as the author had stated, as probably the most important ingredient of the tar. In the last specification which he, Dr. Tidy, had drawn up a year ago, and which was now being employed largely, he had laid down three essentials, and as they practically represented the views which he held on the subject at the present time, he might be allowed to refer to them. The first point of the specification was that the creosote should be completely liquid at a temperature of 100° Fahrenheit, no deposit afterward taking place until the oil registered a temperature of 93°. That point was considered very fully. The temperature at which creosoting was performed was about 120°. It did not appear to him to matter one iota

how solid the creosote was (and he was bound to say that from his point of view the more solid it was the better), so long as it was liquid at the temperature at which the creosoting process was done. Seeing that the process was carried out at a temperature of 120°, he thought he was right in specifying that the creosote should be liquid at the temperature of 100°. The next point was (he had left out a specific-gravity clause) that, tested by a certain process, the creosote should yield a total of 8 per cent. of tar acids. He was aware that in an earlier specification drawn up by Sir Frederick Abel and himself about three years ago, they specified 10 per cent., and of course it was only fair to ask him why he had thus degenerated. Having examined a very large number of creosoted timbers that had been prepared for at least a year, he was unable to detect the slightest trace of carbolic acid in them. This fact had also been very prominently and excellently well brought out by Mr. Greville Williams. But although after a short period there was no trace, so far as he could make out, of carbolic acid in the sleeper, yet the wood continued as sound as ever. It was also a fact that the earlier timbers were creosoted with heavy oils containing only a small quantity of carbolic acid, nevertheless these very sleepers laid the foundation of the success of creosoting at a process. Taking those two facts together, it appeared to him that they had hitherto placed an exaggerated value upon the carbolic acid. He did not wish to be misunderstood. He did not say that the carbolic acid evaporated, nor that it might not undergo certain chemical changes in the wood; he did not know what took place, and that was not the place to discuss the question. It was on the ground, however, he had mentioned, that he had fixed the quantity of the carbolic acid as low as was consistent with obtaining a genuine creosote. In other words, he fixed 8 per cent., not because he regarded 8 per cent. as necessary for the purpose of creosoting, but because he thought from a large number of analyses of London creosote, that by fixing 8 per cent. he should ensure the obtaining a genuine creosote. In the other part of his specification he admitted that he had completely altered previous specifications, namely, in requiring that the creosote should contain at least 25 per cent. of constituents that did not distil over a temperature of 600°. He believed that up to that time almost every specification had required that the oil should contain at least 75 per cent. of matters that did distil over 600°. He entirely agreed with the author that it was to the heavier oils that the success of the creosoting process was due, and it was therefore by the amount of those oils that did not distil over at a temperature of 600° that the excellence of the creosote to be used for creosoting purposes should be determined. It appeared to him to be highly advisable to get the heaviest creosotes for the work, and to insist upon as great a quantity as possible of the creosote being driven into the wood.

Dr. H. E. Armstrong said that, on the whole, he concurred in the views expressed by the author. He thought that creosoting, instead of being an operation of a three-fold character, as Dr. Tidy had stated, was of a one-fold nature. Water had to be excluded, because in excluding water everything was excluded which was likely to be harmful. When water was introduced, other things were introduced with it, especially certain organisms which there could be no doubt played a most important part in effecting the rapid decay of timber. He agreed with Dr. Tidy that, mechanically, it was of great importance to choke up the pores, but the object was not so much to choke up the pores as to prevent the perpetual moistening of the wood. When wood was moistened, and was subject to frequent variations in pressure, it necessarily became after a time reduced to a very spongy condition mechanically, and its quality was in that way materially affected. If, therefore, the access of moisture could be prevented an important point was gained. The author had briefly referred to Pasteur's experiments, which perhaps were not so well known as they deserved to be. He supposed that the experiment to which special reference was made was that conducted with sawdust. M. Pasteur had shown that if ordinary moist sawdust had air passed over it for a few hours, there was obvious evidence of decay afforded by the production of carbonic acid. But if precautions were taken to kill all the organisms attached to the sawdust by heating it, and if it was then

moistened with water deprived of organisms, and exposed to a current of air carefully deprived of organisms by filtering through cotton wool, the current of air would pass over it for hours without there being any evidence of the decay of the wood. That was the fundamental experiment upon which the views of chemists with regard to the part played by organisms were based at the present day. With reference to the author's remark as to the difference between creosote, properly so-called, and coal-tar oils, he thought there was a little misunderstanding on that point. The author stated, "Creosote, correctly so-called, is the product of the destructive distillation of wood, and coal-tar does not contain any of the true Creosote, which has never been used for timber preserving." That was not quite correct, because true creosote contained a considerable quantity of carbolic acid and cresylic acid, which had been commonly regarded as active constituents of ordinary creosote oil. With reference to what was really the active constituent in creosote oils, the remarks of Dr. Tidy met with his approval to a large extent, but he should be inclined to predict that before many years Dr. Tidy would drop his limit from 8 per cent. to 6 per cent., and perhaps eventually sink it altogether. It was very much to be hoped that that would be the case, because he thought that engineers were using a material for creosoting that ought not to be employed for that purpose, and probably the carbolic acid was practically of very little use. He did not think that the coagulation of the albumenoids to which reference had been made, took place to any large extent, or was an essential part of the process. That was, he thought, the only part that could be assigned to the carbolic acid. There could be very little doubt that, within a comparatively short time, either by evaporation or by being dissolved out, the carbolic acid disappeared. It was not there in any form, but actually went away. There was no probability that it would be fixed in such a way as to escape attention and detection by the tests employed by Dr. Tidy and Mr. G. Williams. He was inclined to think the action was mainly a choking action as described by Dr. Tidy, the access of water to the wood being prevented. It was therefore simply a question of obtaining an oil which would do that in the best possible way, which could be introduced into the wood with the greatest readiness, and would remain in it under ordinary conditions, for the greatest length of time; and if, as the author had said, with the oil which would exercise that action engineers could introduce substances like acridine and other compounds of a poisonous character, so much the better.

Professor A. Voelcker remarked that, as had been pointed out by the author, the antiseptic treatment of timber had almost entirely superseded former methods, and justly so, for on the strength of past experience there could be no question that, when properly carried out, the impregnation of timber with crude creosote was the most efficacious, the least troublesome, the most persistent, and the cheapest process that could be adopted. He gathered from the paper that the author was rather inclined to think that chemists had attached too much importance to the presence of carbolic acid in creosote oil. He had pointed out that certain alkaloids in coal-tar possessed antiseptic properties, even in a higher degree than phenol, and had suggested whether it would not be desirable to modify somewhat the specifications issued by the Crown Agents for the colonies, by the War Office, and other public bodies. Professor Voelcker agreed that the heavy tar-oils were extremely useful, and perhaps more so than the light tar-oils, for preserving timber intended to be used for railway sleepers. He could not go so far as Dr. Tidy, who had suggested (he granted somewhat vaguely) that chemists had attached far too great importance to the presence of carbolic acid in crude creosote. But he would go as far as to say that for preserving well-seasoned old timber, it did not, perhaps, matter so much whether there was a high percentage of carbolic acid in the creosote, as it mattered that there should be present in it a high percentage of the oils which passed over on distillation above 610°, because, as Dr. Tidy had pointed out, the effect of these tar compounds was to close up the pores of the timber, to render it impervious to water, air, and other debasing influences; being at the same time in itself, comparatively speaking, an imperishable substance, like all pitchy products when completely

dried. But it should be borne in mind that it was requisite not only to preserve well-seasoned old timber, from which the moisture was expelled almost completely, but that of late years a great deal had been done in preserving telegraph-posts, gate-posts, wooden fencing, hop-poles, and the like, for which sapling-wood, or at any rate young wood, was used. There was a great deal of difference in the chemical constitution of the two kinds of wood. Sapling-wood was more or less filled with sap, and in the liquid which circulated in it there were perishable substances belonging to the class of albumenoids, which acted as ferments, and caused otherwise imperishable substances to decay. The primary causes of decay of green wood were unquestionably the albumenoid substances; and all the older processes, such as the corrosive sublimate, or kyanizing plan, or the impregnation with other metallic salts, were based on the principle that by those metallic salts, notably by the bichloride of mercury (corrosive sublimate), the albumenoids were precipitated, and rendered insoluble and incapable of acting as ferments. In green wood also, the celluloise was in a more tender condition than in old wood, where there was a larger proportion of incrusting matter; there was, therefore, a greater reason for preventing the first state of decomposition; and he questioned whether creosote, which was sometimes extremely poor in carbolic acid, was the proper material for preserving wooden structures of the kind he had mentioned. No doubt there was a good deal to be said in extenuation of the qualities of creosote, for the process of preserving wood in open tanks, was sometimes unskillfully—not to say carelessly—conducted; but, making all allowance for the imperfections of the methods for preserving wooden poles in that way, there could be no doubt that sometimes creosote answered remarkably well, and in other instances the same process tended to make the wood more perishable than it would have been had it not been creosoted at all. That seemed to be a contradiction, but according to the evidence of those who had carried on the process with more or less success for fifteen years or longer, the same kind of creosote would answer extremely well for preserving hard timber used for railway sleepers, while for young wood it did not answer the purpose. He had found, from the examination of samples which had been sent to him, that there were great differences in the composition of different creosotes. Not long ago he had received a sample which yielded, on distillation from the boiling point up to 610°, only 39 per cent. of distillate, containing no more than 3 per cent. of carbolic acid; while another sample yielded 14¾ per cent. of a watery liquid with a little light oil, the water being strongly ammoniacal; and it was well known that any ammoniacal water left in the creosote was extremely injurious to the timber. The same sample only yielded 47½ per cent. of distillate; including 4¼ per cent. of crude carbolic acid. In a third sample he found only 5 per cent. of carbolic acid. He ventured to think that creosote containing as little as 5 per cent. of crude carbolic acid was not a good liquid for preserving immature wood, simply because it was not strong enough to precipitate or render ineffective albumenoid substances. Even Dr. Tidy, in the recent modifications of his views, still recommended that the creosoting liquid should contain as much as 8 per cent. of crude carbolic acid. A great deal had been said about the specific gravity of the creosote. He confessed that he did not attach very great importance to specific gravity, but he did attach great importance to the presence of a fair percentage of phenol, or crude carbolic acid, if it was wished to preserve green wood, such as that used for telegraph posts or hop-poles; because it was essential that the first tendency to subsequent decay should be counteracted, and that could not be done without the introduction of a sufficient quantity of carbolic acid. In the case of hard timber the main object was to fill up the pores. There was not so much albumenoid matter present, and the timber would keep fairly well if moisture was excluded; that was effected by heavy tar oil which filled up the pores, and rendered the wood very hard, so that there was not the same necessity for the presence of carbolic acid. He could even understand that if crude creosote contained a very small quantity of carbolic acid, as in the case he had mentioned, and if there should be a large proportion of the more solid constituents of creosote, the pores externally at any

rate would be closed up, and the same thing would take place by painting or pitching unseasoned wood; the solid constituents closed up the pores of the outer layers, introducing nothing to render the albumenoids ineffective as a ferment, so that the moisture was kept in, and in that way decay was actually hastened, whereas if free passage were allowed, the wood would be washed out and would keep longer. Engineers knew from experience that green wood, when thoroughly painted or pitched, decayed more rapidly than wood in its natural state. In order that the point might be settled he would suggest that some experiments be tried with creosote containing various proportions of carbolic acid, not with reference to the preservation of railway sleepers, but of younger wood. Strictly comparative experiments should be made with crude creosote, one sample containing 5 per cent., another 10 per cent., and a third 15 per cent. that being the usual range of carbolic acid in commercial creosote. Some well-conducted experiments in open tanks with creosote of various strengths would, he thought, finally settle the question. He could not help thinking that it would be requisite for the proper carrying out of the process that there should be something like 10 per cent. of crude carbolic acid in the creosoting liquid; at any rate, without further information on the subject, he should be disinclined to recommend anybody wishing to preserve hop-poles or telegraph posts to use any liquid containing a less amount than he had mentioned.

Mr. H. K. Bamber said it appeared to him that the whole secret of the paper was to be found in the paragraph, "By the light of the evidence now accumulated, it may be advisable to review the question as to the relative value of these various bodies contained in the heavy oils as regards the preservation of timber. Some of them are becoming valuable for other purposes. Which of them should the engineer retain for injecting wood?" Carbolic acid, if left in creosote, was worth 2d. a gallon, and if taken out from 4s. to 40s. per gallon. according to the state of purity. The author's idea appeared to be that nothing should be left in the creosote which it would pay him better to take out; in fact, there should be nothing left that was worth more than the proverbial 2d. He did not appear to see the difference in our color between the two pennies and the two sovereigns. The difference in the town-made tar and the country tar did not arise so much from the difference of coal used as from the degree of heat used in making the gas. In London it was desired to obtain a harder coke that would do for engines, and for that purpose a much higher temperature was used, and the most luminous portion of the gas first formed was decomposed on coming into contact with the sides of the red-hot retort, the result being gas charcoal, naphthaline, and a gas of less illuminating power. With regard to Dr. Letheby's specification, that very specification was advocated and recommended by Messrs. Burt and Boulton, but then carbolic acid had not become so valuable when separated. Now the specification recommended was drawn up by Dr. Tidy, and if the author could get his views adopted there would soon be a very tidy specification to work from. The author had mentioned some experiments of Dr. Tidy's with naphthaline injected into wood, but he had given no facts or data, merely expressing his own opinion. Again, the experiment was not similar to the exposure of creosoted sleepers, which were not subjected to a temperature of 150° Fahrenheit in a closed vessel. He would give the results of two experiments that he had made in 1882, one with country oil, condemned by the author, and one with Mr. Boulton's own oil, full of naphthaline. He took a piece of wood (deal), 3 inches by 3 inches by 8 inches, and dried at 230° Fahrenheit, until it lost no more weight, so that there was no water left in it to cause loss. He then kept it in a vessel containing the author's London creosote, heated to 180° Fahrenheit, having a weight on the wood to keep it under the creosote. It took up 1,020 grains, after being wiped from excess of creosote outside. It was then, on February 7th, 1882, placed on a mantelshelf, where the temperature was never above 70° Fahrenheit, and generally between 40° and 50°. It was repeatedly weighed, and the loss was constant until June 5th, 1882, when it had lost 487 grains, equal to 47.75 per cent. of the creosote put in. Now, as there were only 10 per cent. of crude tar acids in the creosote, what was it that made up the 47.75 per cent. loss?

Water there was none. The loss arose chiefly from evaporation of the naphthaline. At the same time he treated a similar piece of wood, 3 inches by 3 inches by 6 inches—2 inches shorter—dried at the same temperature, until it ceased to lose weight. It was then immersed in country oil, specific gravity 1,045, and kept under the oil by a weight, but without applying heat. It absorbed 1,788 grains of the creosote, so that the wood, which was a quarter smaller, took up, actually, in cold, more than double the quantity that the other piece did of the author's oil at 180° Fahrenheit. The piece was placed side by side with the other on the mantelshelf, and in four months it had lost 575 grains, or 42.33 per cent. of the oil taken up. But that was not fair to the second piece of wood, for it was so saturated that some of the oil drained out on the mantelshelf, and of course contributed to the loss of weight, although it was not by evaporation. The oil contained about 20 per cent. crude tar acids. Those were plain facts, and showed that the author's contention "that country oils are not good for creosoting timber because of their instability" was contrary to fact. The beautiful white substance, naphthaline, was liable to sudden changes. It might at one moment be a black dirty-looking substance, and, by the application of a moderate heat, it became volatilized and condensed into a lustrous substance. The author, by Dr. Tidy's experiments, had tried to make out that it was not volatile. Camphor, although it could not be volatilized by heat without decomposition, yet it was well known that a piece of camphor, even when wrapped in paper or any porous material, would soon pass away by evaporation; and it was so with the naphthaline. Many attempts had been made to prepare tar colors, &c., from naphthaline, but as yet without success; it was worth nothing (except in small quantities in the albo-carbon gas-burners) when separated from the creosote; and that was the reason why it was so valuable, according to the author, in the creosote. But if ever, by chemical research, naphthaline became as valuable as carbolic acid, it would then become so volatile as to escape from the creosote altogether, and chemists would be asked to reconsider their creosoting specifications. As to the solubility of carbolic acid in water and alkaline solutions, which the author said was a disadvantage, he maintained that it was an advantage, for it enabled the acid gradually to dissolve in the water and sap, and thus get into the substance of the wood and prevent decay, while the other portion of the creosote remained like beauty, only skin-deep. To say that because carbolic acid could not be found in creosoted sleepers after twenty or thirty years, and that therefore it had nothing to do with stopping decay, was absurd. It might as well be said that a few days after a large fire only one or two policemen were found and no fire-engines, and that therefore the policemen put out the fire and not the engines. Carbolic acid was an oxidizable substance, and would protect the wood from oxidation or decay. It instantly prevented decomposition, and destroyed the life of the germs which caused decay, being also poisonous to most insects. Dr. Tidy had mentioned the number of analyses he had made, and how long his experience had lasted. Mr. Bamber might therefore be allowed to state that he had tested samples of creosote for the last twenty-five years, and had practical experience in the process of creosoting. It was his opinion that to creosote timber properly the creosote tank must not be only the "waste tub" for distilling works. It was easy to get good country oil with 18 to 25 per cent. crude tar acids, yielding no deposit of that volatile substance, naphthaline. He had met with some samples of so-called creosote that contained nearly half their bulk of filth, consisting of charred oil, &c., he presumed the residues from anthracene manufacture, yet when the creosote was rejected every effort was made to induce the belief that it was some of the best creosote.

Dr. Albert J. Berneys said that no one could doubt the conclusion that the substances preferred should be germ excluders as well as germicides, and those contained in the oils which were heavier than water. His contention would be to retain, at least in part, and to the extent of 2 per cent., the carbolic acid as well as the naphthaline and the alkaloids. The arguments in favor of carbolic acid were very strong. Where the creosoted

timber was covered up in the ground the solubility in water assisted in diffusing it somewhat in the earth, and thus extended its sphere of action. Nor should that solubility be exaggerated. In a dry soil the loss could only be by heat, and that would also affect other ingredients. It said much for the durability of carbolic acid that, in spite of the employment of heavier types of tar-creosote in early days, it was distinctly present in many cases recorded in the experiments of Mr. Greville Williams. In one specimen wood creosoted thirty years, distilled with water, a distinct reaction of phenol was obtained in a case where most of the oil and all the naphthaline had disappeared. In another, creosoted thirty-two years, the phenol reaction was very distinct. In a third, creosoted twenty-nine years, the phenol reaction was very strong when distilled with acid, but was also distinctly present in a free state; whereas there was no naphthaline and very little oil. In cases where no free phenol was found, it was discoverable in combination. The power possessed by phenol for coagulating albumen could not be exaggerated. He would not describe his own experiments; but in his hospital work he was very familiar with the high antiseptic power of carbolic acid. The experiments of Mr. Greville Williams with the white and yolk of an egg only showed that the alkaloids of the tar-creosote, weight for weight, were equal to the carbolic acid as germicides, but certainly no more; and that the $\frac{1}{1000}$th part of phenol bore no relation to the amount of albumen present. If all the albumen had been coagulated it would not have putrefied. For Mr. Williams further stated that 1 per cent. of phenol and 1 per cent. of alkaloidals were of equal value. He believed in the coagulation theory by phenol of the albumen of the wood, but unless enough was used it was as with disinfectants. If he had a quantify of hydrogen sulphide in the air of a room, and he only used enough chlorine to unite with one-half of the hydrogen present, where would the disinfection be? It was the worst of disinfectants that generally they could not be used in sufficient quantities. The benefit of them was (as Miss Nightingale had said) that it was necessary to open the window when they were used. It was the same with phenol. If he did not coagulate the albumen, of which there was but little in the wood, he failed. But the phenol had the property and the additional advantage of volatility. It took a long time for even the free phenol to evaporate, so much was it protected and shut up by the oil and naphthaline in the tar-creosote. And he believed that not only was carbolic acid more potent as an antiseptic than any other constituent of the tar-creosote, but that it was present in larger quantities than the alkaloids which, according to Mr. Williams, were equal to it weight for weight.

Mr. W. Foster regarded the question brought forward by the author, as to the value of alkaloidal substances, as a very important one. In a paper which he had recently read before the Institution, he had remarked on the possibility of some of the nitrogen, which he was then in search of, being in tar in the condition of alkalodial bodies. The author had mentioned five or six of those nitrogenous bodies, and there were probably others. The recent investigations of chemists had shown that pitch itself contained an appreciable amount of nitrogen. Acridine, of which an example had been given in the table, contained the lowest percentage of nitrogen, and had the highest boiling-point. Having regard to the pitch, it was possible that there were other nitrogenous bodies which had a still higher boiling-point, and a lower percentage of nitrogen than in the case of acridine. The quantity of those alkaloidal substances in the tar was very small. There was no information as to their relative proportions; and as the percentage of nitrogen varied from 17.7 to 7.8, it would not be wise to specify how much of those bodies was present in the tar. He thought he might say that there was not more than from 3 to 4 per cent. If, therefore, they had any value in the preservation of wood, their effect must be very powerful. He was inclined to look at the question of the preservation of wood by the aid of some facts which were a little outside the subject. He might be pardoned for referring to the corrosion of iron. Iron could remain permanent in dry oxygen, in pure water, or in pure carbonic acid gas; in any two of those it remained permanent; it was

only by the conjoint influence of the three that corrosion was effected. Pitch, he believed, was the best preservative of iron that was to be had, and if applied to a clean surface free from oxide (rust), it was impossible to say when the surface of pitch would fail to protect the iron. He was of course speaking of the continuity of surface being preserved. Pitch was a substance of a most permanent character, being almost destitute of any chemical attributes; if, therefore, the cellular structure of the wood could be thoroughly permeated by it, as long as the continuity was perfect, it would be preserved. Of course, that could never be fully realized in practice. In the case of green wood, the question arose as to the coagulation of albuminous matter. No need to go far afield to get plenty of instances showing that if water and impure air could be kept out, the preservation would be prolonged. The author had referred to the experiments of Pettigrew; but the inference he had drawn was not the only one. If albuminous matter was dried, it could be kept as a horny substance for an indefinite length of time. A piece of glue could be preserved intact in the same way. If white of egg or glue were moistened and exposed for a certain time, it putrefied. The inferences deducible from Pettigrew's experiments could, he thought, be traced to the removal of water from the muscle (the heart), which had been the subject of the experiments. The whole thing might be summed up in the gravedigger's reply to Hamlet, "Water is a sore destroyer of the dead body."

Mr. W. Carruthers thought that the botanical aspect of the question should be at the basis of the inquiry; for without a proper appreciation of the circumstances under which vegetable tissues were destroyed, it was impossible rightly to appreciate the means by which that destruction could be prevented. While he agreed with much that had been said, he felt bound to differ from a great deal that he had heard. He acknowledged the great importance of pitch for preserving the external surface of wood. But wood decayed not only from chemical agents, air and water; but much more from the action of parasites. He could easily see that if a body was entirely protected externally by pitch, it would be preserved from chemical changes, but not from the more injurious and dangerous attacks of fungal parasites. They were developed from spores, and the attack might be made through a flaw or crack in the wood. When the wood was exposed to the desiccation of the air, flaws continually appeared, and wherever a spore could get access, there would begin development of the mycelium or root of the fungus, which penetrated the wood wherever nutritious materials were supplied through its whole course; so that unless the wood was preserved by some substance which would prevent the life of fungi, its destruction was certain. He exhibited a specimen of wood the date of the creosoting of which was not known, but it had been used in a hurdle for at least ten years. The lower creosoted portion, embedded in the earth, did not show the slightest injury; but the upper part, exposed to the air, and cracked, had been attacked from the outside by minute vegetation. Some of the spores had obtained access to the interior, which had not been antiseptically preserved, the fungi had enormously developed, and the interior had been destroyed by them. The same thing had occurred in the case of two specimens of telegraph poles. The exterior of the specimen which he exhibited had been fairly preserved, but the interior had been destroyed. It was remarkable that the interior was colored by the injection of what he supposed he must call creosote; but it had not been sufficient to serve as an antiseptic, as it had permitted the free growth of fungi, which ramified through the base of the pole and completely destroyed the cellulose or lignine, leaving it a fragile skeleton. It appeared to him that what was needed was a sufficient impregnation of the wood with creosote, and with that element in it which was destructive to vegetable life. He did not know from experiments what that element was, but he did know that there was an element in crude creosote that was extremely destructive to vegetable life, viz., carbolic acid. Not, however, in all strengths, for Koch, a distinguished German mycologist, had found that certain liquids, with 5 per cent. of carbolic acid, would support fungi; so that the presence of a small percentage was not destructive to vegetable life. That was extremely important in relation to the ob-

servations of Prof. Voelcker. Another specimen from a telegraph pole had been completely destroyed by a fungus (*Reticularia*). There was on one side a yellowish dust, consisting entirely of the spores of the plant. But in a specimen from a hurdle, which had been in use since 1861, when it was creosoted, the exterior, although it had no coating of tar, still exhibited the minutest marks of the tools employed upon it, and the interior, which was completely saturated with a brown substance, was as good and fresh as if it had been creosoted yesterday, without a particle of fungus. There was a little greenish vegetation on the outside, but it was epiphytic, and not injurious to the wood; there was no fungal vegetation whatever. The wood had been enormously increased in weight, and he had ascertained microscopically that there was no deposit in the interior of the cells. The whole of the lignine and of the secondary deposits had been colored by that material, so that the tissue had been completely altered. It appeared to him that there had been a new combination through the injected material, producing an antiseptic condition of the wood which was fatal to the fungi. There was a little free carbolic acid crystallizing in the interior of the cells, but it did not seem to him that that was the explanation of it. He should be glad if those who were conversant with the chemical aspect of the subject, would inquire into the real nature of the change which had produced the discolored and altered condition of the lignine. In his opinion nothing had been introduced for preserving timber that could compare with the creosote used in the specimen he had exhibited, which had been exposed to the air nearly twenty years, and yet the ragged edges of the chips on the outside had not even been touched by atmospheric or other destructive agents.

Mr. Henry Maudslay observed that, in the case of Old London Bridge, the decay of the timber piles of the piers varied according as they were constantly under water, or exposed to water, air, and sun; or exposed especially to salt water or to fresh water on the rise and fall of the tide. There were many combinations of circumstances that tended practically to destroy timber, and it was therefore most desirable to ascertain the exact position that would be occupied by a solid pile driven into the earth to support a structure—whether it was to be exposed to the constant action of the water below in the earth, or to a change in the rise and fall of the tide, or to the influence of moisture gradually attacking it above the highest springtide level. On the Arran and Snowdon mountains he had been lately excavating soil in order to form a reservoir, and had come across some of the largest roots of red pine timber that he had seen in that locality. There were no trees on the mountains at the present time, and it must have taken many years for the timber to have grown at that elevation—1,200 to 1,500 feet above the level of the sea. The timber was of a magnificent character; these roots had been submerged perhaps centuries. The roots had been found *in situ* covered with a layer of disintegrated earth saturated with water from the copper mines. They had been preserved in that way by nature, but now that they were being exposed to the air, they were in some cases beginnin to crumble away. The props and supports in old workings of copper mines were preserved, and would burn with great difficulty. Since the Royal George had sunk in 1782, all the timber had become saturated with sea-water, which was so destructive to the cast-iron cannon, that they were made as soft as plumbago; but salt water had a great effect upon the preservation of the oak wood, making it quite green. The timber was so hardened that all the pores seemed to have been filled witn some material that was suitable to its preservation. It still retained that quality, as shown in the case of a billiard table made for Her Majesty, and by another now in his late father's house at Norwood. This table had been made by Thurston in 1860, from the wreck which was raised in 1841. With regard to the decay of iron. he might be permitted to mention that Queen Anne's statue at St. Paul's cathedral, was one of the finest of London specimens of decay of iron that engineers could examine. It consisted of cast iron, wrought iron, lead, and stone, all of which were mouldering away by the action of nature, the character of the air, and the water. The whole of the ironwork was a magnificent specimen of age and deterioration. If chemists would examine the question as to effects produced

upon timber subjected to the continual action of water and its components, or to the rise and fall of the tide, whether salt or fresh, or only to the effects of a certain amount of moisture, as in the case of railway sleepers afterwards dried by the action of the sun, the practical results of their investigations would be of great value.

Mr. E. A. Cowper said he understood that an examination of the old pieces of timber successfully creosoted that had been exhibited, showed they were not at present protected by tar acids, and if they had had any in them in the first instance, it had long ago evaporated. The unsuccessful telegraph pole exhibited by Mr. Carruthers, from which a specimen had been taken, had evidently not been put into a creosoting cylinder, for it had a mere slight covering of creosote outside. Hop-poles were often put into an iron pan with a fire under it and made hot, and there could be no doubt that steam came out from the water evaporating, and the very action of which the author had spoken took place to a slight extent. The piece of wood that was cut to a taper had a little creosote in its end, but on its sides the creosote did not go in $\frac{1}{16}$ of an inch, it was merely paint on the outside; where the mortise-holes had been put through the post the spores had entered and attacked the inside. The effect of a spore getting into a piece of timber that had been preserved only on the outside surface was no argument against the preservation of timber by creosote. The piece from the Victoria Dock fence, which had been well creosoted, had been preserved, and was as sound as it was twenty-nine years ago, when it was put down. The creosote had gone to the middle of the wood and protected it. The other specimen had not been preserved, and, therefore, it was rotten. A very extensive series of experiments had been carried out by Mr. Charles Coisne, and they were of a very instructive character. Samples of creosote had been taken from England, Scotland, Belgium and France, showing 15, 15, 8 and 7 per cent. of tar acids, and there was a fifth specimen of heavy oil without any tar acid. Other mixtures were made by putting in an extra quantity of tar acids, except in the case of the one kept without acid, and the result showed that where the heavy oil was used the wood was preserved in the best manner, whilst those samples of wood preserved with creosote, having an extra dose of acid, were not so well preserved, and that which was unpreserved was entirely rotten. He had gone to Silvertown to examine the apparatus to which reference had been made. There were a number of pipes in the bottom of the creosote cylinder with superheated steam in them. When the timber had been put into the cylinder and warm creosote run in upon it, the temperature was gradually got up, and the water was as effectually driven out of the wood by evaporation as would be the case if water was put in a boiler with a fire under it and kept without any fresh supply of water. A temperature of 220° or 230° would evaporate every particle of moisture out of the wood, more especially when a vacuum was put on. He might mention that the vacuum should not be turned on suddenly, otherwise the creosote, steam, and water would all boil over. Water was deposited in a vessel in connection with the condensing pipe, together with some light hydro-carbons. The creosote supplied to the creosoting vessel being heavy oil, would not commence to boil until about 392°. London creosotes contained about 4 to 7 per cent. of tar acids. He had himself tried some experiments in coagulating and precipitating albumen, and he found that considerably less than 2 per cent. of carbolic acid in the creosote would precipitate the largest amount of albumen found in wood, so that there was amply sufficient carbolic acid in the London creosote for that purpose. Not only was the albumen coagulated by the two per cent. of carbolic acid, but by the mere fact of its being boiled. If an egg was boiled for a short time the white would set, and in an hour or two it would be very hard. After the vacuum had been on for a sufficient time, and the whole of the water and moisture withdrawn from the timber, the cock was turned, and the pressure put on with pumps up to 120 lbs. to the square inch. Not only did the pumps put on the pressure and force the creosote into the wood, but directly the temperature was lowered a little, steam condensed, and there was a vacuum in every pore of the wood. The whole of the

wood was made a condenser; in every pore that had previously contained water there was a vacuum, so that the creosote went in, and, besides that, there was the pressure of 120 lbs. to the square inch. At the works he saw a whole range of tanks, following one after the other. He thought the method was a very practical and mechanical one. There could be no doubt about the creosote thoroughly entering the timber. He thought the thanks of the members were due to the author for the admirable way in which he had developed the subject. The only thing wanted was a sort of skeleton specification for their guidance in the future.

Mr. W. H. Preece said that as the behavior of certain of Her Majesty's telegraph posts had been called in question, he ought to say something in their behalf. For the past thirty years he had devoted all the attention and skill that he could command to the inquiry as to the best modes of preserving timber. In the telegraph service of the country many millions of poles had been preserved in various ways, and one of the methods—that explained by the author—had proved to be the survival of the fittest. A great deal had been said as to the various causes of decay. Reference had been made to chemical and physiological causes, but there was a third cause, which might be called mechanical, of the decay existing at the "wind and water" line, or the ground line, where the timber was exposed to incessant changes of moisture and temperature. A careful microscopic examination showed that the process of decay was a purely mechanical one, that the wood disintegrated by a process of bursting. The fibers appeared to be minute boilers, and the change of temperature produced evaporation, minute explosion, and rapid deterioration. It was a simple thing to meet the chemical cause by the insertion of salts of various kinds, and it was possible to meet the physiological cause by antiseptic treatment; but the mechanical cause could only be obviated by coating the fibers of the wood with waterproof material, and filling them with a thick, viscous mass like creosote in its best form. In 1844 the first line of telegraph was constructed between London, Southampton and Gosport, and the posts were made of the best Memel timber, preserved by the burnettizing process, simply impregnating the wood with zinc chloride. In 1857 he made a personal observation of a great part of the line in different grounds, and found that in sand about 40 per cent. of the posts had gone, in clay about 33 per cent., and in chalk about 28 per cent. In 1860 he found that the proportion was much greater, and in 1871 they had all failed, so that they had to be removed. The burnettizing process materially added to the life of the pole without rendering it indestructible. Kyanizing was tried to a small extent, but the poisonous character of the salt deterred him from carrying it further. The favorite process about twenty years ago was that of boucherizing. The authorities had purchased whole forests, and in the middle of them established the boucherizing process, by which they had succeeded in lengthening the life of timber considerably. While the life of an average telegraph pole unprepared was about seven years, the life of a boucherized pole was about fifteen years. In 1848 a line of poles was erected from Fareham to Portsmouth, a distance of about 20 miles, and all the poles, three hundred and eighteen in number, were creosoted by Mr. Bethell. It 1861 he examined them all *in situ*, and only two showed the slightest trace of decay, and they had begun to decay at the top. In 1874 he had them again examined, and every pole was sound. Last year, owing to the requirements of the service, and the necessity of increasing the number of the wires, the line of poles had to be taken down, and although they had been put up in 1848, they were as sound as when they were first erected. About the year 1861 the question of the proper mode of preserving timber was one of great consequence. The authorities were not satisfied as to which was the best, boucherizing or creosoting, and consequently, as the Yeovil and Exeter line of the London and South-Western Railway Company the poles were put up alternately: first a plain pole, next a boucherized pole, and next a creosoted pole, the line extending about 40 miles. In 1870 he had them carefully examined, and it was found that of the plain poles that had been up ten years not one existed, all

having decayed; while of the boucherized poles 30 per cent. had gone, and of the creosoted poles not one had decayed. The result was that the Government had decided for years past to creosote all their poles. He did not remember the exact specification that was used. At present the millions of poles existing in the country were all creosoted. It was true that some of them had failed, but, as Mr. Carruthers had pointed out, there was creasote and creosote. There were unreliable firms, and others in whom confidence could be placed; there were inspectors who could be trusted, and others who could not. There were poles about the country supposed to be creosoted that were rotten; and it had been found that those particular poles had not been inspected, and that they had been hastily and improperly impregnated. He could state, as the result of thirty years' experience, that he had never seen a case of a properly creosoted pole showing the slightest sign of decay.

The reply of Mr. Boulton upon the Discussion and Correspondence is given at the end of the Correspondence.

CORRESPONDENCE.

Mr. A. Bouisson, of the Western Railways of France, stated that in 1859, on the line from Rouen to Dieppe, sleepers creosoted by the Bethell process had been adopted for the first time. These sleepers were of beech. They had been creosoted in England in the works of the author's firm, and when an examination of them was made twenty years later, on the occasion of the Paris Exhibition of 1878, it was shown that not a single one of them bore the slightest trace of decay. Since 1864, the railway company of which he was engineer of the permanent way, had adopted creosoting for their sleepers, and from that date they had applied it to about five million sleepers, of which at least three million and a-half were of beech wood. In these latter, as in the trial sleepers of 1859, no sign of decay has as yet been distinguished, and the lasting powers of the sleepers seemed only to be limited by the wear and tear to which the materials were exposed. Beech wood placed in the ground, without having been prepared, completely decayed at the end of two or three years, which rendered impossible the use of that wood unprepared in the form of sleepers. Also sulphating, employed for a long time for beech sleepers, not having given the good results expected, had been abandoned by all the French railway companies.

The employment of creosote for the preservation of sleepers had given every satisfaction, and its use had only been limited at certain periods by the difficulty sometimes experienced in procuring a sufficient quantity of creosote. As regarded the quality of the creosote, he simply required that it should contain 5 per cent. of phenic acid.

Mr. W. A. Brown remarked that a preserving process, of which much had been said and a great deal expected by engineers a few years ago, had been referred to in the latter part of that portion of the paper devoted to "Apparatus for Timber Preserving." This process was Mr. Blyth's system of "Thermo-Carbolization," which had been carried out by Messrs. Conner & Co. at their works at Millwall, when a large number of sleepers had been prepared for some of our railways, together with telegraph poles for them and for the Post Office. It became his duty, about four years ago, to inquire into the subject, and he made an investigation into the different stages of the process at Messrs. Conner & Co.'s works, which led him to the following conclusions:

1st, that the strength of the wood was impaired through some of the celluloise and its incrusting materials being carried off in the form of pyroligneous acid by the superheated steam.

2d, that the peculiar "Creosote mixture" used as part of the process, contained so large a proportion of water that it was not at all likely to act as a preservative of the sleepers to which it was applied.

It would be interesting to hear now how the sleepers and poles thus prepared had actually lasted in this country. In Austria the experience of Mr. Seidl, and in France that of the author, as recorded in the paper, appeared to confirm the conclusions at which Mr. Brown arrived in the course of his investigations; but so far as he was aware, there were no published results as to the process in England.

Mr. John Cleminson observed that the

question of preparing timber against decay was occupying more attention now than formerly. It was therefore to be regretted that the author had not referred in detail to many good processes with the above object in view, namely, that of Sir John MacNeill, Gardner, Beer, Blythe, and others. The author's remarks in reference to carbolic acid as an antiseptic would lead to the idea that it was necessary the acid should remain when injected; such was not the case, nor was it necessary. The mere fact of its presence (the most powerful antiseptic known), with superheated steam, was all that was required to produce coagulation of the albumen, and so to render preservation practically complete. With the old process of creosoting, the surface exteriorly only was preserved, the interior if unsound decayed uninterruptedly. All depended upon the selection of the timber. No amount of creosote would avail to save its destruction ultimately, if the interior was not sound. Where sleepers were adzed, the greater part, and in many instances the whole of the part, penetrated by the creosote was cut away, thus leaving the interior open to destruction from damp and other causes. The same disadvantage was experienced in the case of piles, when the ends were pointed for receiving shoes after creosoting. With carbolic acid once in contact with the albumen, and in the event of any interior unsoundness, the coagulation arrested decay, and prevented it from spreading, by entirely enclosing the defective part or parts. Combined when necessary with an outer application of creosote, thorough soundness and preservation internally and externally were thus secured. Blythe's process was a double process. The object, preservation internally and externally, in the case of sleepers and piles, was most effectually obtained by carbolizing the interior, and creosoting the exterior. A result had been obtained that had placed this process foremost with French engineers for several years, and it was now largely used by them. In England where used it had met with much favor. The author of the paper was employing this process in France.

Mr. Richard Cowper remarked that the value of creosote for preserving timber depended partly on the mechanical effect which it had in excluding from the pores of the wood air and water, and the germs of destruction which they contained, and partly on the power possessed by certain of its constituents of destroying those germs. For the purposes of germ-exclusion, it was generally admitted that the heavier portions of the creosote, from the less degree of solubility and volatility which they possessed, and their property of solidifying at ordinary temperatures, were the more efficacious. As regarded the germ-destroyers, the phenols and the alkaloids alone need be considered. Phenols, namely carbolic, cresylic, and other acid bodies occurring in creosote, had long been known to possess remarkable antiseptic properties, but they were easily soluble in water, and comparatively volatile. Much stress had been laid upon their power of coagulating albumen, but it had been shown that no stable chemical compound was formed, and that the albumen thus coagulated might be freed from the phenol by washing with water, when it would decay. It had been shown by the experiments of Coisne, Greville Williams, and the author of the paper, on pieces of old creosoted timber, that in many well preserved specimens no phenol can be detected by the ordinary test, whilst in most cases they had found naphthaline, and in all cases oils of the heaviest character in considerable quantity. It had been shown by Mr. Greville Williams that all the old timbers examined by him contained a considerable amount of alkaloids, and his experiments proved not only that these alkaloids were powerful germicides, but that they were more powerful than phenol. They were at the same time much less soluble and volatile. Evidently if creosote containing a high percentage of phenol were required, it could not contain so high a percentage of the heavier constituents, which were those possessing the greatest value as germ-excluders. At the same time, some of the alkaloids which had been shown to be of more value than phenol as germicides would be removed.

Mr. W. Langdon remarked that in 1874 a paper by him upon the subject had been read before the Society of Telegraph Engineers, in which he warmly advocated the employment of creosote in preference to any other preservative for timber, and

he had since seen no reason to alter the views expressed on that occasion. Of late years, however, the appearance of the timber so treated had suggested the belief that the oils now employed did not contain that amount of tar or other heavy compounds which was apparently possessed by the creosote supplied in the earlier days. His attention in the application of creosote to timber had been more in the direction of telegraph poles than otherwise, which class of timber was much more exposed to the weather than were railway sleepers, and which might in consequence be accepted as affording a more complete test of the value of the oil than did railway sleepers. These to a great extent were buried in the soil, and had but one side exposed to the influence of the atmosphere. Of late years numbers of the poles had presented anything but the appearance of a well creosoted pole. The surface had become partially or wholly bleached, and almost white. This generally occurred on that portion of the pole subject to the sun's rays; but it was also equally marked upon that side of the pole exposed to prevailing winds and wet weather. It would therefore seem as if the bleaching was the result both of the influence of the sun and of the weather; in fact that the creosote disappeared from the surface of the pole under the influence of the sun and of wet. If telegraph poles creosoted many years back were examined, as a rule the surface of those poles would be found covered with a pitchy compound, and that mainly on the side of the pole exposed to the sun. There was no washing out from the weather. This he thought was easy of explanation. The warm atmosphere would always exercise an extractive influence upon any oil injected into wood or other like substance; its tendency would be to bring it to the surface, where the lighter portions would be evaporated, and the heavier portions congealed. Creosote no doubt was a strong antiseptic, but where timber when felled was decayed, it could not give fresh life to the decayed portion. Timber, if properly seasoned, would last many years if not exposed to the vicissitudes of wind and weather, as in the instance of many articles of furniture made from the very same wood from which telegraph poles and railway sleepers were obtained, and which seemingly never decayed indoors. It was here that the creosote process enabled an equally long life to be obtained for it when employed out of doors, and he imagined that the heavier oils played a much higher part in procuring this immunity from decay than the creosote oil, inasmuch as it was to these heavier oils that the exclusion of moisture from the timber was due. A telegraph pole, or a railway sleeper, free from disease, if properly seasoned, and encased in such a manner as to prevent moisture getting into its fiber, was practically indestructible from rot or decay. The coating given to it by the injection of these heavier oils into the fiber to a depth of from 1 to 2 inches afforded the timber this coating, excluded moisture, and thereby secured its duration.

Mr. C. De Laune Faunce De Laune remarked that the author had attempted to prove that only a very small quantity of carbolic acid was necessary in creosote for the preservation of wood. He approached the subject with diffidence, as he lay claim to no scientific knowledge, merely discussing it from the purely practical side; and because he had been instrumental in extending the use of creosote among landowners and farmers. The author referred to his having used creosote too hot, and thereby having damaged the wood, much in the same way as if he had taken a warm bath too hot. He certainly stated to the author that he had used a material called creosote which contained a very small percentage of carbolic acid, and that the wood had failed to be satisfactorily impregnated with it in an open tank, even when submitted to a great heat; but he scarcely anticipated that he would infer that it was his general custom to use extreme heat, as he only wished it to be understood that even under such conditions the creosote did not perfectly penetrate into the wood. The process of injection, in the case of telegraph poles, might preserve them to an indefinite period, but such a course was frequently impracticable to the former, and in the case of hop-poles impossible; wherefore an open tank was indispensable. For the last twenty years he had used creosoted wood, and the process had always been performed in an open tank. The wood was first cut to the required shape, and then immersed in the creosote which

had previously been liquefied and warmed by a furnace built underneath the tank. No thermometer had ever been used to regulate the heat, and the only precaution taken was to prevent the creosote from boiling over, though it was sufficiently heated to make a few bubbles appear on the surface. Wood of all kinds had been used, and no difficulty in applying the creosote was at first experienced, but he believed that the creosote had gradually been becoming worse and worse, and so he submitted it to Dr. Voeckler for analysis, and got the following reply: "Your creosote has a specific gravity of 1.103, and on being subjected to distillation yields only 61 per cent. of volatile oils, of which 4 per cent. are carbolic acid." My experience in creosoting timber, small as it is when compared with that of public companies, is large for a private individual, as I have at this time 46½ miles of fences where creosoted wood is used; and whereas the system, when employed some years ago, was satisfactory, the present results are as much the contrary. The pieces of creosoted wood exhibited by Mr. Carruthers were creosoted by me in 1866, and, as was pointed out by him, are perfect in their preservation. Unfortunately I have no analysis of the creosote then used, for such an analysis would prove that a material of the same constituents would be suitable for preserving wood in an open tank. It was obvious, therefore, that a creosote was formerly used that could and did preserve inferior wood in an open tank perfectly, and which could be used so easily that no particular precautions as to the dryness of the wood were necessary, and it was in the hope of ascertaining the component parts of the creosote which he once used with such admirable results, that he ventured on these remarks; for the creosote that he formerly used for preserving wood was as valuable as that which he was now using was useless and worthless, and all he asked of manufacturers was to give him material like what he had before.

Mr. W. Lawford wished to inquire how it was that, in the face of such undoubted proofs of the value of the creosoting process, some of the large railway companies, and notably the Midland, had given up creosoting their sleepers? He considered it the duty of every one who used timber largely to adopt either this or some other antiseptic treatment, since large encroachments were annually made upon the timber-growing districts of the world, without an adequate supply of timber-producing trees being planted for the use of posterity.

Mr. C. Lowe, in reference to the constituents of the creosotes employed for "pickling" or preserving timber, was disposed to attribute to the tar acids only a very small amount of the effective results obtained by the application of the creosote, for the following reasons:

1. Carbolic and cresylic acids were both completely volatile even at an average summer temperature in England, and in hot climates could not long remain present (except as traces) in any timber to which they had been applied.

2. Both these acids were readily soluble in water, and would consequently be rapidly removed from the timber in case the latter, previously saturated with them, was subjected to the action of water in motion. He regarded the action of coal-tar creosote in preserving timber as presenting a two-fold character; first, a mechanical action, by which the wood was rendered waterproof from the filling up of the cellular tissue with matter insoluble in water; second, a chemical or antiseptic action, due chiefly to the presence of the tar acids. These tar acids were roughly divisible into the readily volatile acids soluble in water (carbolic and cresylic), and the heavy, almost non-volatile, acids insoluble in water. The latter class had not been thoroughly studied, but it was known to be powerfully antiseptic, and anti-parasitic. He therefore considered the creosote best adapted for the "pickling" of timber to be a creosote containing sufficient solid hydrocarbon, such as naphthaline, to be solid at a temperature slightly above the average climatic or other temperature to which the timber was to be ultimately exposed; at the same time, to prevent the attacks of parasitic insects, etc., the heavy tar acids should be present. No reliance should be placed on carbolic and cresylic acids for pickling timber, seeing they were so readily removed by the action of water and climatic heat. It was well known

that their albuminous combinations were readily broken up by simple washing with water; as germicides and antiseptics, when retained *in situ*, these acids were invaluable for surgical use and disinfection, and to these purposes they should be relegated.

Mr. T. E. M. Marsh exhibited specimens of timber used by the late Mr. Brunel in 1839. These were fair samples of the bulk of the timber of the ribs of the skew bridge over the River Avon, at the Bath station on the Great Western Railway. The timber was cut from Memel balk, and was kyanized. It was quite sound after forty years' service. The kyanizing process had been employed extensively by the late Mr. Brunel in the early works of the Great Western Railway. The permanent-way timbers were thus prepared, and gave excellent results as to preservation from decay, as was shown by specimens cut from various parts of the line, between London and Bristol, after having been laid from fifteen to twenty years. Mr. Marsh had gained much experience in the preparation and uses of creosoted timber, both while acting for Mr. Brunel, and subsequently up to the present time. In the early days of the process, the tar from which creosote was prepared was not subjected to the extraction of so many chemical ingredients as was now the case, and the naphthaline, or salt precipitated was comparatively small, and considered of little value. No difficulty was then experienced in getting a good admixture of light and heavy oil in a fluid state, of satisfactory color, consistency and taste, and complying with the rough and ready tests adopted. Mr. Brunel adopted the process extensively from its early introduction by Mr. Bethell, in bridges and permanent way, and much of those timbers and structures remained in use at the present day. It was, however, soon discovered that it was of great importance the timber should be well seasoned and dry, and that it was worse than useless to creosote unseasoned, damp or wet timber. Some alarming cases of internal decay had been discovered, attributable to these causes. Of late years, on account of the greater demands on the timber merchants, and for other reasons, the preparation of creosoted timber had not always had such careful consideration. The processes were often carried on, not only not under cover, but water in variable quantities was generally found in the tanks from which the oil was pumped into the pressure-cylinders, and solid salts and a mixture of mud and the residuum and drainage of objectionable matter from the timber of preceding charges, accumulated in the tanks and returned again, to the detriment of subsequent charges. It not unfrequently happened that timber coming from the pressure-cylinders might be found with some portions presenting no trace whatever of creosote even on the surface, but showing only signs of the contact of dirty water, when the quantity of creosote injected was supposed to have been 50 gallons to the load. Such facts, Mr. Marsh asserted, were sufficient to account for many reported failures, without reference to the chemical questions as to the relative values of the constituent parts of the oil. Mr. Marsh's instructions to his inspectors for the preparation and pickling of timber, where thorough efficiency was desired, were based on his own personal observations, and were as follows:

"The state of the tanks from which the creosote is being drawn while the pressure progresses, and before any creosoting is done, must be examined, and if found to contain salty or muddy sediment at the bottom, or water at the top, or the nature of the creosote otherwise bad, its use must be protested against. Samples must be taken by a tube dipped to test the liquid at various depths, particularly the upper and lower portions of about 12 inches of the top, and the same at the bottom. This must be strictly attended to. No steam shall be let into the creosote anywhere. The numerous pipes used for heating, and sometimes hoses and joints, may give the means of mixing in steam during the process, and hence the condensed water, which must not be permitted under any circumstances. Sometimes the appearance of the timber after creosoting will show that water has been in contact with it. The thorough good creosoting must also be checked by a chisel at the sound hearty parts of the timber, and the penetration checked by weighing trial sticks with each charge (these should

not be open sappy timbers, and they should be the least dry rather than those to favor absorption more than the bulk in the same charge). A good percentage, over 50 gallons to the load, must be injected so as to allow for outside drainage when drawn out of the cylinder. In weighing, 50 gallons may be reckoned as 550 lbs. If the timber be not quite satisfactory and perfectly dry, and immediate delivery is urgently wanted, then a considerable extra quantity must be injected, as much as 10 per cent., or further drying, and under cover, must be insisted upon, but in no case must positively wet or damp timber be allowed to go into the pressure cylinders."

Mr. Benjamin Nickels observed that he was much gratified in noting that the author had drawn special attention to the compound acridine, pointing out, at the same time, its high antiseptic value as a constituent of creosoting materials. It would appear that his impressions had been based on certain marked properties exhibited by this peculiar substance, notably its intense pungency, acridity, and high antiseptic value, also its immunity from loss by evaporation and the solvent action of water. As little beyond a mere reference to the compound had been made, it might be of interest to state what had been done in other directions, and so far as it might corroborate the views advanced by its author. In the year 1882 he was induced to take out a patent for a composition to be used as an insecticide, and for the coating of ships' bottoms and other submerged surfaces, and in which acridine played an important part. He had, during a previous experience, met with many opportunities of observing the painfully irritating action of the heavier tar oils, arising from handling during the treatment and purification of anthracine, due to the presence of acridine, and as an outcome of the observation it had occurred to him that this substance should constitute an effective "antifoul," inasmuch as it would be almost impossible for animal life to remain in contact with it. Experiment in numerous directions fully supported the idea; but the question arose, would the acridine resist the prolonged solvent action of water, and remain effective for a lengthened period, and in the thin coating of any composition that could be applied as a paint to a ships' side? Opinion varied considerably as to ultimate success when attempted on a practical scale, although laboratory trials had shown that such composition was unacted upon in still water. The first experiment of any importance was made on a small iron barque (the "Cordova") which sailed from London for the Falkland Islands about the end of January, 1882, returning at the end of October, after an absence of nine months, during which her hull had been constantly submerged. Previous to sailing, portions of her plates towards the lower part of the vessel, and where subjected to the greatest wash, had been coated in the ordinary way of applying a ship's paint with acridine composition, prepared in conformity with the patent referred to. He was present on her return to England, and upon the vessel being docked for repainting and repair, he made a close inspection of the portion that had been originally coated with the composition. He found that the paint had remained intact, presenting a smooth and unbroken surface; it had adhered most tenaciously to the iron plates, completely protecting them from the action of the sea. There was no adhesion of barnacle or weed, and the evidence of contained acridine was very manifest on applying the tongue to portions of the composition scraped from the side of the vessel. Subsequent examination showed that there had been little or no loss of acridine, and that the prolonged and beating action of swiftly-running and boisterous seas had failed in removing or washing out the acridine originally incorporated in the paint applied. Since the date of this experiment many others had been made, and were still on hand, with vessels on long sea-voyages, and, as far as he was enabled to state, the results obtained had been of a satisfactory character.

It would be difficult, perhaps, to cite more complete illustrations of the indifference of a substance to severe water action; and the author might, he thought, rest well assured that his statements concerning this singular tar product were in nowise overrated or exaggerated. As regarded the antiseptic character of acridine, he might mention that it was of high value, extremely small quantities be-

ing sufficient to arrest the change in many organic substances prone to rapid decomposition.

Mr. Martin F. Roberts wished to direct attention to a point which had influenced engineers in their preference for the so-called "Country oil," viz., that of economy. Engineers would be aware that in drawing up specifications it was usual to stipulate for a certain quantity of creosote to be injected into a cubic foot of timber, usually 6, 8 or 10 lbs., the contractor's price for creosoting being regulated according to the quantity specified; and it thus became necessary for engineers to consider whether, say 8 lbs. per cubic foot of the thick, heavy, London creosote penetrated as far into the timber as 8 lbs. of the thinner country oils. He was sure all engineers would agree that it would not; and from his own experience he was able to say that, with telegraph poles, in many places where 8 lbs. of London creosote per cubic foot had been injected, it had not penetrated more than half through the sapwood, whereas a similar quantity of country oil would have penetrated completely to the heartwood, although, of course, the country oil would not leave as large a deposit of solid substances in the pores of the timber. It was, therefore, desirable to consider whether it was better to have the sapwood completely injected with thin oil at a certain price, or the outer portion only injected with thick oil at the same cost, and his experience led him to prefer the complete injection by the thin oil. His ground for arriving at this conclusion was that, although he had met with many samples of creosoted timber in which a portion of the sapwood had decayed where the creosote had not penetrated, he had never met with a piece of timber having decayed where the creosote had penetrated, except in one instance in a Government telegraph pole, referred to in the discussion; and even in this case he thought it well to ask if the decay had taken place before or after creosoting. Engineers acquainted with red fir timber would remember that what was called a "foxey pole" was occasionally found, in which, although the outer portion or all of the sapwood might be quite sound, some of the inner portion of the pole had decayed before felling; and it was often a difficult matter, even for an experienced inspector, to detect such a pole. It would easily be conceived that in such a case the decay might be, and often was, attributed to a defective quality of creosote having been used, instead of to the fact that a portion of the pole was rotten when treated.

The remarks made by the author under the heading of "The Conflicting Theories of Putrefaction," in which he spoke of the "gaping orifice of a crack produced by the sun in a piece of timber," would appear to specially point to the necessity for the use of a thin, penetrating oil, as timber would crack after long exposure in the sun, even if it had been creosoted with the thickest London oil; and in these cases the oil which had penetrated the deepest would be more effective, as it was the most likely to have genetrated beyond the depths of the crack. If it were the practice to completely saturate the entire mass of timber with creosote, and if it were found possible to do so in all cases, there would then be no objection to the use of London oils; but as the question of cost had to be considered, and the smallest quantity of creosote per cubic foot which was found to answer the purpose was therefore specified for, the thinner country creosote was preferred, owing to its greater penetration, weight for weight. In Mr. Coisne's experiment with shavings, the conditions were so totally different to those met with in ordinary practice, that too much reliance should not be placed in them. It was obviously an easy matter to completely saturate shavings either with thick or thin creosote, but with telegraph poles and railway timber the creosote never penetrated completely through the timber, and it could not be contended that the exclusion of germs alone prevented putrefaction, as, if so, a coating of tar would prevent decay. What was necessary was that the germs of decay in the timber should also be destroyed, and this could only be accomplished by bringing all that portion of the timber more liable to decay—viz., the sapwood—under the influence of a creosote of considerable penetrating power. If evidence in support of this assertion were needful, it would only be necessary to refer to the fact that engineers strictly barred the use of whitewood timber for telegraph poles and other purposes, owing to its

being found impossible in practice to inject creosote into whitewood to a greater depth than ½ or ¾ of an inch from the surface, and whitewood timber so prepared, either with London or country creosote, was found to decay rapidly. It would appear that the best system of creosoting would consist in first injecting the timber with thin "country oil," then running the thin oil off and filling the cylinder with London creosote, which, being forced in by increased pressure, would drive the thinner oil further into the timber, and the thicker creosote would hermetically seal the outer pores of the timber. Failing this process, owing to its increasing the cost, it would appear advisable to use thin creosote, and if it was considered that thin oil did not sufficiently fill the outer pores of the timber, the process, at a trifling cost, could be supplemented by giving the timber a coat of hot tar.

Mr. Greville Williams stated that he regarded the paper as the most valuable and exhaustive contribution yet made to the literature of the subject. He agreed with Dr. Meymott Tidy and the author in considering that the value of the carbolic acid in creosote oils had been overrated. He believed that an oil from which the carbolic acid had been removed would sterilize wood, if thoroughly impregnated with it, partly by virtue of the organic alkaloids present, and partly by the protective influence of the heavier oils themselves. He had satisfied himself by careful experiments that the alkaloids exercised a potent influence in preventing the development of bacteria, mould, and microscopic fungi in vegetable infusions. He thought, moreover, that where wood had to be exposed to the action of seawater, it would be advantageous to use a creosote containing a high percentage of the alkaloids; this could easily be attained by well-known methods. Although the minute quantities of carbolic acid remaining in old creosoted timbers were too small to account for their preservation, he considered it right to say that, by a sufficiently delicate method of manipulation, he had rarely failed in getting evidence of its presence even thirty years after the wood had been creosoted. He found traces of it in eleven out of fourteen specimens which had been creosoted from twenty-five to thirty-two years before. The organic alkaloids, however, which remained, were sufficient to allow quantitative estimation. He thought that no chemist, who had examined very old sleepers for carbolic acid, could come to any other conclusion than that the traces remaining were insufficient for their protection. A point, moreover, of great importance for the proper comprehension of the subject, was involved in this almost entire disappearance of the carbolic acid. If the coagulation of the albumen by the carbolic acid were the cause of the preservation of the timber, how was it that this acid almost entirely disappeared? The instability of the compound, of albumen with carbolic acid, was well known to those chemists who had minutely examined it; nothing more conclusively proved this instability than the disappearance of the carbolic acid. With regard to the naphthaline, he thought it significant that it was only absent from two of the sleepers he had examined. There could, he considered, be no question that naphthaline, although perhaps feeble as a germicide, properly so called, was very valuable as a sterilizer; it was insoluble in water, and once in the wood, clung to it tenaciously. He was also most decidedly in favor of the removal of all restrictions as to maximum boiling-point, and considered that, if the oils were fluid at the temperature of injection (say 100° to 120° Fahrenheit), that was all that was needful. On the whole question, he found himself able to thoroughly indorse the conclusions of the author and Dr. Tidy, and he considered that specifications which excluded the use of London oils were framed under a misapprehension of the true nature of the condition requisite to afford a good creosote.

A PATENT taken out for a yellow metal, by T. Parker, describes it as of great tensile and compressive strength and hardness, and made by melting copper, 50 parts; spelter dross, 25-30; spelter, 12-17; tin, 2½ parts; with a flux of the following composition made into a paste: Salt cake, 5 parts; coal-dust, 5; silica, 15; bone ash, 20 parts. Manganese or copper sulphate, or the chlorides of these metals, and also common salt, may be used in place of the salt cake. This flux is also applicable to the founding of brass and bronze generally.

TECHNICAL EDUCATION.

By HENRY CUNYNGHAME.

From the "Journal of the Society of Arts."

The question of technical education is one which is daily growing into greater importance. The report of the Technical Education Commission has afforded fresh information as to the condition of technical schools abroad, and the efforts which have been lately devoted to the subject have attracted public attention at home. There is, however, one application of technical education of which I wish particularly to speak this evening, namely, its relations to the apprenticeship system.

By technical education is meant instruction in the art of applying the discoveries of science to the requirements of modern industry. It is not scientific teaching, in the strict sense of the word, nor, on the other hand, is it mere craftsmanship. It is rather the application of science to craftsmanship. To take an example, the mode of treatment of electrical subjects given in the works of the late Professor Clarke Maxwell is purely scientific and mathematical; in his hands electricity is an applied mathematical science. In the hands of Faraday, electricity becomes an experimental science. But neither the teaching of Faraday nor Maxwell is of exactly the kind that is suitable for a mechanic—something more practical is needed; the body of truth must be arranged rather with a view to action than to knowledge. This requires a bent of mind that is midway between science and craft; it is the liberal part of the education of an artisan. We require manual dexterity, guided by wide views, and scientific knowledge accompanied by executive power. Hence it follows that it is useless to expect the technical school to take the place of the workshop, or a technical course of instruction to replace the apprenticeship system.

How often does the engineering training given to some young gentleman result in making him a mere theoretician, an architect who cannot lay a brick, or a surveyor who does not know as much of detail as a small practical builder? And, on the other hand, how many artisans are there, of excellent practical skill, whose efforts are not guided by any scientific knowledge, and who work entirely by rule of thumb? They even distrust and dislike theory, not recognizing that the true aim of theory is to classify and embody the soundest rules of practice.

This truth is seen more clearly when we read the lives of original thinkers like Watt or like James Nasmyth. Their success consisted in the art for which, as a nation, the English are so conspicuous, of reducing theory to practice, and again, of evolving theories out of practical results. So far from theory being opposed to practice, no great success can be achieved without an intimate union of the two, and no rule is safe nor result sound, unless both are blended into harmonious union. Here is the true aim of technical education.

In the report on technical instruction of 1884, it is recommended not only that charitable endowments be applied to technical instruction, but even that local authorities should be empowered to establish, maintain and contribute to the establishment and maintenance of technical schools and colleges. This recommendation is calculated, and with reason, to alarm the mind of the already burdened taxpayer. He may well ask whether, having undertaken to educate all the children in England in the three R's, he is, in addition, to be saddled with the expense of teaching every artisan his trade. And when the enormous expense of technical instruction is considered, as displayed in the details of the two volumes of the commission, the ratepayer may well shrink from the prospect.

It is, therefore, incumbent on the friends of technical education to consider how it may be most economically carried out; and I believe it will be found that the solution of this question lies, not in attempting to replace workshop training by classes or lectures, but rather to supplement it by theoretical instruction. And the best time of life to do this is during the period when the mind

is most receptive, namely, during those years in which the artisan is serving his apprenticeship.

It is often rather hastily said that the apprenticeship system is dead. I think that nothing is a greater mistake. I believe that if careful inquiry were made, it would be found that most good artisans have been apprentices, and that the greater part of boys now learning trades are serving five or seven years. But there a great difference between the apprenticeship system of to-day and that of the past. In former times the apprentice was usually an inmate of his master's house, who boarded, lodged and clothed him. Now, the boy, in general, lives with his parents, or else with some relation or friend, generally paying for his keep, at least in part, out of his earnings.

Moreover, the spread of handicraft literature has almost destroyed trade mysteries or secrets, and the result is that, in the greater number of trades, no premium is now required from a boy on his going into articles for seven years. On the contrary, he generally begins with low wages, averaging apparently about 5s. per week during the first year, and rising to 15s. or 18s. per week during the last.

The strictness of the system depends greatly on the nature of the trade. For instance, in those trades which are not greatly subject to foreign competition, trade societies are usually powerful—as, for instance, the bookbinding trade. Most of the shops or factories in these trades are society shops, and therefore it is exceedingly difficult for a workman to obtain employment unless he has served his term of apprenticeship, and his articles have been duly *vised* by the officers of the society.

In other trades, such as clock and watch making, the competition from France, Switzerland and America is so formidable that the societies have but little power, and hence the apprenticeship system is laxly administered.

Now, I think that all attempts at technical education will be imperfect that do not, to a certain extent, deal with the apprenticeship question. It is in the workshop that the artisan must be really formed; just as the barrister must be trained in chambers, or the doctor in an hospital. At the same time, what the university is to the advocate or medical man, the technical school should be to the artisan; only, however, with this difference, that it is generally necessary that while he is learning, the artisan should also be working, and that his technical instruction should go on contemporaneously with his workshop employment. At present considerable sums are yearly spent out of charity funds in paying fees on indentures. With some exceptions, I believe that money so spent is almost wholly thrown away. Since the masters are, in most trades, willing to take boys without a fee, the payment of a fee only enables the charity trustees to bargain with the employer for higher wages for the boy, and thus to cause the fortunate inhabitants of some ancient precinct or parish to secure one or two shillings per week pay more than their fellows in the same shop—a result which, it must be admitted, is not desirable.

Moreover, under the present system, sufficient care is not taken to select for the boy a trade that is suited to his ability. Indeed, under the present system, this is impossible. He is asked by the trustees, or by their clerk, what trade he would like. Now, it is notorious that boys have the very vaguest ideas of what they desire. Some tale by a friend, or some story in a boys' journal, supplies them with a picture of life, and in most instances they only ask for a light trade and a kind master. The articles are then signed and the money paid, and the seven years' contract is irrevocable. In too many instances the boy only finds that he has embarked in a career that he dislikes, and the master, that he has got an unsuitable apprentice.

Moreover, under the present system, the boys are not sufficiently looked after out of work hours. Whatever may be our opinion of the undesirability of overparentalism towards men, there is no doubt that it is good for boys to feel that there is someone who has authority over tkem, and who desires their welfare, who takes an interest in their work, and who will endeavor to rescue them if they fall into dissolute habits. No one who has witnessed the work that the late General Gordon did among the ragged boys of the suburbs of the East of London can ever under-estimate such influences. To exercise such supervision

has ceased to be the master's duty, and now it is left to chance. Hence it is that anyone who will visit the lower and cheaper music-halls of London will find them crowded with apprentices about seventeen years of age. Here it cannot be said that their taste is improved, or their habits of sobriety encouraged, and here too often they form friendships which lead them into extravagance and idleness, and often connections with the other sex that are immoral and undesirable, and end by producing lives of misery for others besides themselves.

To counteract the evil I have spoken of, there appears to me no more useful plan than to form youths' institutes. The duties of the officials of these institutes should be to see to the apprenticing of boys, encouraging them to enter such trades as offer good prospects, and endeavoring to guide their choice. In all cases a month's trial without pay should be insisted on, and free liberty given to master and boy to refuse the proposed contract at the end of the time. There is no fear that, under such conditions, a boy will desire to change too often.

At such institutions lists should be kept of masters desiring hands, and of boys desiring to learn trades. The character of the masters should be carefully investigated with a view to ascertaining whether they are fit and proper persons, or whether they have lately been bankrupt, and are likely not to be able to fulfil their engagements.

Moreover, the boys should be periodically inspected, a monthly report being given by the master respecting their conduct; and, on the other hand, steps taken to compel the masters to stand fairly by their side of the contract.

It may be a matter for question whether the society should aid a master in punishing an apprentice who runs away or steals. At present, when an apprentice breaks his articles, few masters will take the trouble to prosecute him, and hence is laid the foundation for the idea, so prevalent among all classes of mechanics, that no working man is to be considered in any way bound to a contract. This is a source of constant loss to masters, and results in lower wages to men, and nothing would counteract it so effectively as to force boys, from their earliest years, to see that if they make a contract they are to be bound to stick to it.

I do not believe that it will be necessary or beneficial to pay the apprenticeship fees out of charity money. Quite sufficient aid would be given by lending it, subject to gradual repayment, say, of 6d. per week out of weekly wages.

Such institutions should be closely connected with, and form part of technical schools. Most of the classes would naturally be evening classes, and the subjects so chosen as to be useful to the boys in their various trades. And it would undoubtedly much conduce to the efficiency of such institutions if a certain number of working men could be placed on the committee, to give the benefit of their experience, and to inspire the boys and their parents with confidence.

During their apprenticeship, the boys should be encouraged to exhibit proofs of their skill, for which exhibitions should be awarded; and one of the best forms that scholarships could take would be the setting free of the industrious boy for a few more hours a day, in order to devote the time to study at the institute. Periodical exhibitions give a boy pride in his work, and encourage the feelings of enthusiasm with which the apprentice in older days was wont to regard his "masterpiece."

And to my thinking, the technical school should not stop here. Amusement and exercise are as needful for boys as instruction; and while it would not be right to spend either money given by charity or raised by taxation in providing amusements, still institutions such as I have named might lend spare rooms or yards for gymnasia or recreation purposes, or might provide baths and refreshment rooms, where tea and coffee, or even dinner could be got, but so always as in these respects to be self-supporting. A public library available for all classes would be a useful adjunct.

The above scheme may perhaps seem very extensive, but it is no more than I feel persuaded can be done without an extravagant cost, provided economy is carefully studied.

Moreover, a system akin to this is now in operation with the best results, in the excellent charity organization in the East-end of London managed by the

Jews. They have unusual difficulties to contend with, owing to the boys, from religious reasons, not being able to work on Saturday; and yet they have so arranged matters as to make the apprenticeship system adopted by them almost self-supporting.

And this leads me to lay before you a few considerations upon the expense of technical education. In such institutions scientific apparatus is a necessity.

It behooves, therefore, the friends and advocates of technical education to endeavor to discover whether the cost of this apparatus cannot be so decreased as to bring it within the reach of the masses, for certain it is that if technical instruction is so costly as it has hitherto proved, it is not to be expected either that the working classes should pay for it, or that the expense should be inflicted upon the public.

Every amateur who has dabbled a little in science, no less than every man who has made it his profession, knows the expense of scientific instruments. If he wants to measure the length of a wave of light, there is a bi-prism to be bought, mounted in its stand of polished brass, with a parallel slit in another similarly polished stand, a collimating lens, and a similarly mounted telescope, which, added together, make up a pretty heavy sum when purchased from one of our instrument makers.

But people are not sufficiently aware, because they have not been taught, that as far as the verification of the theory of light goes, such wave lengths can be measured with all the accuracy that educational purposes require, with a small piece of visiting card, a piece of fine wire gauze an inch square. and a two-foot rule, total cost, say 1d.

In the same way, a spectroscope can be made out of paper tubes, cheap lenses, a few pieces of glass, and a little bisulphide of carbon, at a total cost of, say, 5s., which will divide the D sodium line in a manner quite sufficient for the instruction of mechanics. Instances of this kind might be multiplied indefinitely.

There is no scientific instrument of any sort which cannot be made to serve for educational purposes, at a cost of as many shillings as it now costs pounds. But such a mode of study and teaching requires certain rules to be rigorously adhered to. In the first place all lacquer, French polish, ornamental paint, and varnish, must be strictly discouraged, and even forbidden. The students must be taught not to spend one moment on ornamentation of any kind. The one aim must be accurate fit and adjustment of essential parts, and absolute indifference to all others. This rule is harder to enforce in practice than might be imagined. When a new microscope comes home from the maker's, its polished mahogany case is opened, and to the eyes of the beginner, a vision of splendor is revealed in the golden gleam of the shining lacquered brass. All this he must studiously avoid. It is the mere joy of a child in a new toy. His only care or thought ought to be whether the lenses are optically true and achromatic, and, with these conditions satisfied, he should be carefully weaned from the prejudice in favor of varnish and veneer.

I saw, lately, a spectroscope by a leading London firm. Nothing could be more elegant than the finish and polish of the brass, but on investigation the axis was found too short, and not truly in the center of the dividing plate, and the tube of the collimator was actually half an inch too long. A better result could have been obtained with some pieces of wood and cardboard than with this forty-guinea instrument. If half the time spent in polish and lacquer had been bestowed on accuracy in the essential parts, the instrument would have been worth double the money.

The first benefit of the adoption of the system of making the students construct their own apparatus is, therefore, economy. All that is needed is a store of flat glass, glass tubing, wood of different sizes, brass discs, screws, wire, and various chemicals, and a few simple tools, such as a fine tenon saw, pliers, and a few files, while for general use, a glazier's diamond, a grindstone, and a large dividing protractor and steel scale, a pair of accurate balances, and a few such apparatus, should be in every laboratory.

The comparative list in page 138 will show, as an example, corresponding sets of instruments. In the second column is placed the price as usually charged by a good instrument maker; in the third,

the price at which an equivalent instrument can be constructed by the student; in the fourth, the time a skillful workman would take to make the instrument and adjust it. (Of course beginners would take far longer.)

On the table I have here a set of tools and chemicals with which many of the apparatus here before you were made, and which is amply sufficient to make all that are given in the above list. The cost of the whole comes to £6 10s. The details are given on a card placed on the table. In this way a sum of £20 would go far to set up a technical class with the necessary tools and appliances, while if it were desired to do more elaborate work, the addition of a lathe, bench-vise, set of drills, and other simple tools could be made for about £60. But not only is economy consulted by this system of teaching, the instruction is far more efficient. Suppose, for instance, it be desired to exhibit the qualities of polarized light. Whether will it be better to buy a shop-made polariscope with all the adjustments already made, or to cause the student to place his reflector at the true polarizing angle, to secure it there with neat pieces of cork and sealing wax, to place his bundle of microscope glass plates in a tube, again securing the proper angle of inclination, and to tinker up the instrument till it works, at an outlay for materials of, say, a shilling? Which of two students will use a really fine instrument the best, one who has been trained in the manner here advocated, or one who has always been provided with instruments ready made?

It must be remembered, too, that this course has always been followed by the great discoverers. We read of Newton discovering the shadow fringes of light, by means, as he tells us, of two pointed knives ground flat, and with their points pricked into a board. He misunderstood the causes of the phenomenon, but Fresnel afterwards discovered and explained them with no better apparatus than some pieces of cardboard and sewing thread. Mr. Justice Grove's first battery consisted of a wine glass, a tobacco pipe, and some bits of metal.

It is not sought here to depreciate accurate instruments. For purposes of measurement by an observer engaged in original research, no refinement can be too delicate, no mechanism too good, but the path of the student should be upward towards these things, through a course of study with self-made apparatus.

Moreover, such construction teaches the learner the use and nature of materials. You may, perhaps, remember the construction of a reflecting galvanometer if it has been taught to you—perhaps you may forget it; but if you have once wound a coil with 3,000 turns wrong, and had to unwind it, we may certainly count on your not doing so a second time. If you have cemented a liquid prism with marine glue, and filled it with bisulphide of carbon, you will not probably repeat the error.

	£ s. d.	s.d.	Hrs.
ELECTRICITY.			
Thomson's reflecting galvanometer.	10 10 0	8 0	12
Ordinary galvanometers	1 17 0	2 6	6
Tangent galvanometer	3 0 0	2 6	4
Resistance coils	2 10 0	4 0	9
Lamp and scale	0 15 0	1 6	1½
Magnetic needle	0 2 6	0 1	¼
Set of magnets	0 1 6	0 2	¾
Thermopile	0 17 6	0 8	2
Four-battery cells	0 6 0	0 8	1½
Magnetometer	1 1 0	0 2	2½
Small portable do	?	0 1	¼
Induction coil and condenser.	0 10 0	4 0	5
Electrophorus	0 5 0	2 0	2
Leyden jar	0 2 0	0 8	1
Condensing electroscope	0 3 0	0 1	1½
Dry pile	0 5 0	0 6	1½
Quadrant electrometer	10 0 0	3 0	15
LIGHT.			
Spectroscope	5 5 0	5 0	8
Wave length measurer	?	0 1	¼
Liquid prisms	0 15 0	0 6	¾
Refraction measurer	5 5 0	1 0	4
Polariscope	2 10 0	1 6	2½
Concave and convex mirrors.	0 4 0	0 4	1
Telescope*	2 10 0	2 6	8
Photometer	0 5 0	0 2	½
Spirit level	0 1 6	0 2	¼
SOUND.			
Monochord and weights	1 10 0	0 8	3
Glass tube for dust figures	0 5 0	1 0	2
Telephone	0 6 0	0 6	1½
Microphone	0 5 0	0 4	1
HEAT.			
Expansion machine	1 0 0	0 8	2
Differential thermometer	0 5 0	1 0	2
Alcohol thermometer	0 1 6	0 3	2

* An excellent lecture on "How to Make a Telescope for 2s. 6d.?" was lately given to boys by Prof. Norman Lockyer.

The neat use of blowpipe, the handling of heated glass, the use of paraffin wax for the countless purposes to which it is applied in the laboratory, are of themselves an education of the highest value, not only to those who are to be engaged in original research, but also to those who are to become foremen or artisans. But it might be, perhaps, objected that the method consumes too much time. This, of course, would greatly depend on the teacher. It is not proposed that a student should make every conceivable piece of apparatus. For instance, it would be absurd to expect him to try and rule a diffraction grating. And, again, his instruction will be supplemented by daily lectures, at which more elaborate experiments will be performed by the professors. It is, however, always found that all knowledge takes time to penetrate, and as it were to suffuse the brain, and while the fingers are working the mind ought to be thinking.

It may further be asked whether such a system as is here advocated has ever been tried, and with what results. The answer to this is that such a system has been, and is being, practically worked in a few places, and it is much to be wished that it were greatly extended.

The merit of practically applying, if not of inventing this mode of instruction, is probably due to Professor Guthrie, of the Science Schools, South Kensington, and every year in the summer teachers are taught in this manner how to teach. At the end of the course an industrious student will go away armed with a whole cabinet of scientific apparatus (for the apparatus becomes the property of the pupils who make them), and with this he would be able easily to teach a school. In technical schools, wherever practicable, it should be made a condition of appointment that at least the assistant demonstrators and lecturers should be able to use their tools well.

Too much pains cannot be taken to inculcate this system. Let prizes, if needful, be given for the simplest and cheapest apparatus which shall secure a result of a certain specified degree of accuracy, and encouragement of this kind will speedily provide a scientific set of apparatus in every village school.

Therefore I urge that it is time that if technical education is to be widely spread, it should take the form of a system, that rigorous economy should be practiced, and while no salary is grudged to a competent professor, he should be required to work with cheap materials. The problem is not so much how to do it, as how to do it cheaply.

When, however, we reflect on the splendid ability that is in this country being devoted to technical education, when we read the names of the professors at the great educational establishments scattered over England, we must certainly feel that we have ample guarantee for the solution of the problem.

Moreover, these establishments are on the increase. Not to speak of the Finsbury Institute, there are several smaller ones which are well worthy attention. The Horological Institute in Northampton-Square, aided by a small grant from the City Guilds, is doing admirable service; and the munificence of a private gentleman, Mr. Quintin Hogg, has provided an institution which now numbers 3,000 youths as members, 2,000 of whom attend evening classes, which are also attended by 4,000 more youths who are not members of the institute. By this institution, which occupies the site of the old Polytechnic, 7,000 young men are benefited and provided with physical and mental training and recreation, and assisted in keeping out of mischief. I believe that the original outlay did not exceed £30,000, and that the yearly total cost of maintenance is about £7,000, of which a large part is covered by the fees and subscriptions.

To attempt, at public expense, to do what can only be done in the workshop, is a mistake; it will fail in its results, and it is unjust to expect the nation to pay for it, but it has been endeavored to show, first, that in attempting to improve technical education, some attempt should be made to deal with the apprenticeship question; and, secondly, that at an almost nominal expense, and by the application of a proved method already in use, practical technical science may become a part of the education of our town and and rural population.

It need only be added that it is highly desirable to make the boys and their parents pay, as far as possible, for the benefits they receive, and no money is such

an excellent investment of capital as that which is wisely laid out in education.

DISCUSSION.

Dr. Gladstone, F. R. S., agreed with the reader of the paper that this question was one of primary importance. Whether the system of apprenticeship still continued or not, there was no doubt that it was less common than it was formerly, and that in some trades it was dying out. In any event, technical classes were required, for though he held that no trade could be learned except in the workshop, still those would make the best of the instruction given them in the workshop who had had a certain amount of theoretical foundation laid beforehand. These classes might be formed in various ways, and an excellent example had been referred to in the case of the Polytechnic Institution, where so many students were being well taught various matters which would be of great service to them in connection with their handicrafts. He did not think it was desirable to teach trades in the elementary schools; what should be taught there should be what would be useful to all the scholars, not to a portion of them only. People were gradually working up to this idea, but still vaguely. Many wanted something definite, in the shape of carpentry or iron-working, and seemed to think this was the true kind of technical education; but it should rather be their aim to give such a notion of the value of materials and the use of tools as could afterwards be turned to use in any required direction. There were two great difficulties in the way of doing this in elementary schools. The first, and greatest was the inveterate notion that education consisted of book-learning. No doubt, centuries ago, when education was the privilege of the few, and schools were intended mainly for those who were to enter the professions, the chief part of education was of a literary character; but now that education was become the right of the masses of the people, the problem was entirely altered. Children should be taught that which would be most useful to them in after life; they should not be trained for professional men, or even for clerks. No doubt they should have that simple kind of literary education which would make them all clerks, because mere clerkship ought to be the lowest kind of work; but, beyond that, they should be encouraged to develop some kind of skill. It was very difficult to get over this kind of prejudice in favor of a literary education, and, while it lasted, the knowledge of science and the arts would not take their right position. Another difficulty was the ignorance of teachers in this respect. If an endeavor were made to introduce some knowledge of science into schools, they generally found that the teachers had some kind of theoretical knowledge, but it had been obtained mainly from books; and what was chiefly wanted was that things should be taught as well as words, and before words. He did not say things only. They wanted *res et verba*, but the *res* must come before the *verba*. Pupil teachers had to give object-lessons, but they were not taught or examined in this subject. This was one of the greatest wants in connection with the system of education. Some of these difficulties, however, could be, and he hoped were being, overcome. The idea that education must consist in the teaching of literature was giving way, and subjects of fictitious importance, such as spelling and good pronunciation, would, he hoped, soon be considered less material, whilst a knowledge of the world in which we lived, the forces with which we had to deal, and the materials which must occupy the attention of the great mass of the community, would attract more attention in future. Some of these difficulties might be got over by the peripatetic system of teaching science which was employed in Liverpool and Birmingham with great success, and he was glad to say the London School Board was about to introduce it experimentally. In one way or another he trusted the desired end would be reached, and that the long-suffering ratepayer would have more for his money than he had hitherto, and that the next generation would grow up more capable of doing the work of the world.

Mr. B. Lucraft regretted that he could not agree with Mr. Cunynghame in his view of the present state of the apprenticeship system. His opinion was that there was scarcely a good firm in London who would take apprentices. An employer wanted to get his work done as quickly as possible, and would not be

bothered with apprentices. He should like to see, in place of the apprenticeship system, and with a view of preventing all the clever boys in London turning their attention to clerkships, scholarships given in technical schools with a workshop attached. At present most of the clever boys went into the Post-office, or a place of that kind, for he found that nine-tenths of those who won prizes, when asked as to their future career, expressed such an intention. Some of the scholarships now given to clever boys were, he was sure, an injury, rather than a benefit to them. If institutions were established where the whole theory and science applicable to certain trades were taught, combined with workshop instruction, a class of artisans would be raised up superior to any which could be obtained in any other way. The apprenticeship system in London was almost done with. He had worked in workshops, and most of his acquaintance did the same, and they had the greatest difficulty in getting their sons apprenticed in any way. Some employers would take a boy and give him so much a week, so long as he behaved himself, but they would not take apprentices. Boys trained in such an institution as he had referred to—learning both theory and practice—would become overseers and foremen, and ultimately masters. He gave evidence on this subject before the Royal Commission, and suggested that some of the City endowments which were left to encourage trade might be devoted to such purposes which would be quite in accordance with the views of the original donors, though carried out in a way more suited to the present time.

Mr. G. N. Hooper said this question was now moving a little, though not fast enough in the opinion of many who were interested in it. In the first place, the Council of the London Chamber of Commerce passed a resolution, about a fortnight ago, to support and make known the benefits which would result to trade and commerce by a further development of the system of trade education; and, secondly, on Friday next, a meeting would be held by the Artisan's Technical Institute, at which Mr. Woodall would preside, when both employers and workmen would be present to consider this question. This was a step in the right direction. The subject had been treated by scientific teachers, and by the City Guild, many members of which were not practically connected with trade, and it had not been so favorably received by manufacturers as if they themselves and their workmen and foremen had been more consulted. As chairman of a technical class, he had seen excellent work done at an expense of less than £100 a year, the class averaging 40 to 50, and some who had passed through the course had done remarkably well, and would exert an influence on their trade which could not fail to be beneficial. Some people thought that technical education must be extremely expensive, but that was an error. There were a large number of school-rooms which were totally unused after dark, and they might be made available for this purpose, at a small expense for cleaning and lighting. As one of the jurors at the Paris Exhibition of 1867, he found the French were making considerable advances, and he followed up the matter by visiting the schools, becoming acquainted with the teacher and the students. On the first opportunity he had sent a suitable man over to Paris to be trained, and having had previous instruction in science, drawing, and manual labor he was able to take full advantage of the opportunities offered him, and since his return had been very useful as a technical teacher. A second one had since been sent, and thus the method of teaching usual in France had been transferred. A few days ago, in the *Chamber of Commerce Journal*, there was a quotation from the *Bourse Lyonnais*, showing that the French were dissatisfied with the progress they were making compared with other nations, and stating that in Germany upwards of 100,000 workmen were passing through the technical classes. But these facts did not come out very often. During the Paris Exhibition he attended a meeting of a group of syndical chambers, and took notes of the discussion, but the president afterwards requested him to give these notes to him, saying it was not permissible to take away any record of the proceedings. That, perhaps, might account for the fact that they did not hear much of what was going on in foreign countries; but the manufacturers in this country were beginning to feel

the pinch. The most efficient teachers were found to be properly trained artisans who had studied the sciences applicable to the occupation they followed. Difficulties were often met with in practice which no mere professor could get over.

Prof. Guthrie, F. R. S., said he only claimed a part of the merit which had been attributed to the work which had been going on for ten years in the Science Schools at South Kensington, though he was responsible for it, for he had been most ably supported throughout by the demonstrators, whose assistance it had been his good fortune to secure. When he first entered on the work, he found that the teaching of physics in this country was almost purely theoretical; and, having been trained as a chemist, he reflected what sort of a chemist that man would be whose training had been derived entirely from the lecture theatre and from books; and the question occurred to him, could not elementary physics be taught practically. Then it came to a question of expense, because he had to teach teachers. So it became necessary to devise a system, a sketch of which had been given in the paper, of getting typical apparatus for showing the elementary principles; it had to meet the wants of the teacher, and it must be absolutely and scientifically correct in principle. Mr. Cunynghame had spoken rather too slightingly, he thought, of some of the instruments, saying they did not reach the accuracy attained by an ordinary instrument maker; but he should say that such apparatus as was shown was far more scientifically and absolutely accurate than that which would be produced by the ordinary optical instrument maker. It was simple in construction, but truthful in conception, and without any adornment. This method of bringing the hand and the mind to work together really lay at the basis of all true technical instruction; where the mind alone was employed, the knowledge acquired passed away, but when the mind and the hand had been educated together, the knowledge was never forgotten. For the last ten years his life had been devoted to the development of this particular branch of knowledge, and he could not understand its being so little known and appreciated.

Mr. E. C. Robins said the impression left on his mind by visiting the technical schools in Germany was that the difference in the education of the two countries lay rather in the sections of society above the artisan class, and that the middle classes in England were most backward with regard to scientific education as compared with the Germans. All our schools were practically literary, they were not divided into polytechnic and real schule, and even science was taught more from the literary side, and less awards were given for it. He was astonished to find that so many of the working classes were profiting by the advantages offered them as Mr. Hooper had stated, but if it were true that information was not readily obtainable, that might account for the general ignorance on this subject. If foreigners were making such progress, it was all the more important that England should wake up to the importance of the matter; and, as an architect, he might say he found very few men who had passed through such a training as enabled them, properly, to execute the work they were called upon to undertake. He knew one large firm in the West-end where there was not a single apprentice taken. Another large firm, a little way out of town, employed chiefly apprentices, and some years ago, when a strike took place in the building trade, they were able to carry on their works without any trouble in consequence. There was a great difficulty in this country in getting proper instruction for youths entering the building trades; it was a favor to got them into a shop at all. He thought the trades' unions, if they were worth anything, ought to see to this; but, on the contrary, he understood they rather set their faces against apprentices, and seemed only to think of getting as much money as they could out of the master, and of giving as little as they could for it. He had heard that stated, broadly, by a representative of a trades' union at a public meeting, much to the astonishment of everybody present. There was a great fright with regard to technical education, on account of the expense involved in teaching apparatus, and he hoped this paper would do some good in helping to remove that impression. To that end he would suggest that the simple apparatus exhibited

should be photographed, so that the idea that nothing could be done without expensive appliances might be exploded.

Mr. William Trant (Secretary, Artisans' Technical Association) said the reader of the paper seemed to make a great point that a certain piece of apparatus which took fifteen hours to make only cost 4s. 6d. He did not know whether he meant to convey that technical education would enable people to work for less than 4d. an hour, but if so, that would not meet the views of artisans. All were agreed that technical education was a good thing, and almost all were agreed as to the mode by which it might be carried out; but with regard to the question of apprenticeship, there was much more room for discussion. Mr. Robins seemed to think trades' unions were very much at fault in this matter; but he would remind the meeting that they were not altogether to blame. They had found hitherto that they had to teach the apprentices for the benefit of the employers alone; and not only that, but that they enabled the youths to enter into competition with themselves, and thus the feeling naturally arose that they were cutting their own throats. The rapid improvements in machinery and other things had really revolutionized the system. Apprenticeship as it formerly existed could no longer be maintained, and they had now to consider how youths were to be trained in their respective trades. The question was whether some responsibility did not rest on the employer, and also on the Legislature, to see that lads who were apprenticed should be turned out skillful workmen. The committee which was to meet on Friday, to which Mr. Hooper had referred, would have to specially consider this question. Allusion had been made to lads who ran away from their work, and ought to be compelled to go back. It seemed to him that was just the way to make bad workmen, for unless they had a dislike to the trade they would not leave it. He agreed with what had been said, that the best persons to teach were those who understood the trade itself, and who in addition had received a scientific training. Such men were always looked up to and respected by the students, and produced the best results. As much as possible should be taught at school, and he wanted to see how technical education could be given before it was known what trade a boy was going to adopt.

The Chairman said the account just given of industrial schools was certainly not universally applicable. He had been particularly interested in seeing the Artane Industrial School in Dublin, where several trades were excellently taught, and he believed, and should be glad to hear, that the same thing was done in England. The endeavor of Mr. Cunynghame to show how apprenticeship might best be combined with technical instruction was of great value, whether they agreed with his conclusions or not. He believed him to be right in saying that the technical school could not take the place of the workshop, for experiments made in this direction in various countries had not proved very successful. There was the school, which was very much praised, of the Boulevard de la Villete, in Paris, which was visited by the Commission of which he was chairman; the expense was enormous, and the results were certainly not satisfactory to their mind. Notwithstanding that, similar schools were being established in Paris, and he could only say he was glad the experiment was being made on the other side of the channel. He did not believe that artisans and manufacturers distrusted theory to the same extent as formerly, but, on the contrary, it was more understood that theory and practice must go hand in hand. At the same time, if it was necessary to choose between theory and practice during the time which a boy had to spend in learning his trade, practice should have the preference. There the Germans seemed to make a mistake; they kept the young men, especially of the higher grades, at the Polytechnic School to the age of 22 or 23, and when they entered the workshop to begin their practical training they were, especially from the excessive attention paid to the higher mathematics, unfitted for it. He was glad to hear that Sir F. Sandford approved of the introduction of drawing as a class subject into the new Code; in his opinion it was more important that a boy who was to be an artisan should learn to draw than that he should learn to write.

Drawing not only trained a man to represent correctly what he had seen, but it forced him in the first instance to observe correctly, and no quality could be more valuable to an artisan than that of accurate observation. They would all be glad to hear from Mr. Trant that employers and employed were about to discuss the question of apprenticehip, but he did not think it was a matter in which the Legislature could interfere. It seemed to him a short-sighted policy on the part of artisans to discourage apprenticeship; if they felt an interest in the pursuit in which they were engaged, they could not evince that interest better than by training up good men to follow after them. Besides, many of them were fathers of families, and it seemed to him that, by an interchange of services in this way, the whole of their class must be benefited. He felt bound to say a word in praise of the good work in which Mr. Quintin Hogg was engaged; he believed the amount he had expended was nearer £80,000 than £30,000, but at any rate, the work was a most excellent one, and he had devoted his whole life thoroughly to it. He was also glad to hear what was proposed with regard to Christ's Hospital, and a better model than the Allan Glen's School could not be found. It was carefully examined by the Commission, and he was prepared to say that no more practical system of technical education for boys of the age received there was to be found in Europe.

He was extremely glad to hear that the Horological Institute was so successful; a school of a similar kind at Besançoh was not by any means a success, nor was a similar school lately started in Paris, there being only twelve or eighteen students in the latter. No material impression could be made on the trade at large by a school of this kind, which was only adapted to those who could expend a considerable amount on the training of their children. What could be done was to encourage apprentices to combine with their practical training theoretical instruction, and of that he did not know a better example than the school which Mr. William Mather, of Salford, had established in connection with his own works. By the introduction of such schools into workshops, by the combination of several masters whose workshops were not sufficiently large to enable them to do the work alone, or by encouraging the youths to attend technical schools, like that at Manchester and Oldham, which had been supported liberally by Messrs. Platt, the great work of technical education would best be forwarded. He concluded by proposing a hearty vote of thanks to Mr. Cunynghame.

Mr. Cunynghame, in reply to Mr. Trant, said he had not included anything for time, but only for materials, in the figures he had given of the cost of apparatus. The value of the time would be difficult to estimate, as the students' time would be worth nothing, while the professor's would be worth a great deal. In some trades he believed it was true, as Mr. Lucraft said, that the apprenticeship system was practically dead; in the building trade it was very rare indeed, but in the bookbinding trade all the best shops in London were society shops, where no man was allowed to work unless he could show seven years' indentures properly discharged, and with the mark of the Bookbinders' Society upon them.

He hoped that some of the societies which were inquiring into this subject would endeavor to obtain statistics, without which their knowledge could not be exact. He had tried to get them from Mr. Quintin Hogg's schools, having asked numbers of the boys if they were apprenticed, whether they paid any premium, and so on, and in the majority of cases he found they were apprenticed. A single person, however, could not obtain full information on this point; it must be the result of organized inquiries. If they were to replace the apprentice system by industrial schools, as Mr. Lucraft proposed, was it only to be for the benefit of clever boys? If so, what was to be done with those who were not so clever? And if it were to extend to all boys clever or not, the expense would be so enormous that it would be impossible to carry the scheme out on a large scale. They must do something cheap, as well as they could, and it had been his endeavor to show that a great deal could be done very effectually, and at a small cost.

THE PROTECTIVE POWER OF ARMOR PLATES AS PROVED IN ACTUAL WARFARE.

From "The Engineer."

In view of the protest so ably put forward by Sir E. J. Reed and other well-known naval authorities, against the system adopted by the Admiralty of leaving a large portion of the hulls of our modern ironclads wholly unprotected by armor, a brief summary of the resistance to shot afforded by armor protection in the ironclad actions which have been fought up to the present time may be of interest. We purpose, in this article, to refer to those engagements only in which ironclads have been opposed to armored and unarmored ships of war, and shall reserve the subject of "Ironclads *versus* Forts" for a future occasion, omitting in both cases the actions fought during the war between the Northern and Southern States of America, as both the armor and ordnance employed by the contending parties was of too makeshift a character to be of lasting importance.

In their resolve to denude the ends of our modern ironclads of all armor protection, the Admiralty appear to have been governed by the opinion that thin armor plating is worthless. Theoretically this assumption is correct, and the various experiments at Portsmouth, Shoeburyness, Gâvre, Kummersdorf, Amager, Kolpino, Steinfeld, Muggiano, &c., apparently give this theory a practical backing, which, however, is completely overthrown by the experiences of actual warfare, as will presently be shown. It is, of course, desirable that the heavy guns, &c., of our ironclads should be provided with the thickest possible armor protection, provided that the efficiency of the vessels as fighting machines is not thereby impaired. The question naturally arises: "Are the unarmored portions of our latest ironclads so constructed that, if riddled by shell from even the worst gun at present afloat, no detriment will ensue to the steering qualities of the vessels?" The answer to this question is obvious to those who are acquainted with H. M. S. Colossus and her sisters.

The Battle of Lissa, fought in July, 1866, by the Austrian and Italian fleets, under the respective commands of Rear-Admiral Tegetthoff and Admiral Persano, affords the first instance of a modern ironclad engagement—modern in so far as both parties were in possession of *bona-fide* ironclads and of rifled ordnance. The Austrian ironclads engaged at Lissa were all armored along the entire extent of their water lines, the plating ranging from 2½ in. to 5 in. in thickness. The aggregate armament of the seven armor-plated ships consisted of 173 guns, 74 of which were 6-in. rifled, cast-iron, Wahrendorf breech-loading guns, and the remainder 48-pounder smooth bores. The Italian ironclad fleet numbered twelve vessels, four of which were but imperfectly protected at the ends, viz., the Re di Portugallo, Re d'Italia, Varese, and Palestro. The total number of guns was 248, all rifled, ranging in caliber from the 6½-in. Cavalli breech-loader to the 9-in. Armstrong muzzle-loader. It is unnecessary to dwell further on the events of this battle than to refer to the damage by shot sustained by the respective fleets. The official Austrian report says: "The resistance of the ironclads was not generally put to a very severe test. With the exception of the Habsburg and Don Juan, none of the armor-clads exhibited shot marks with impressions nearly approaching those produced on trial by 48-pounder cast-iron shot with a charge of 14 lbs. of powder at a range of one cable. The greater portion of the projectiles struck obliquely, and a single coating of paint generally sufficed to render the shot marks invisible. Several shots struck the Habsburg below the armor belt, bulging and cracking, but not perforating the wooden hull. The Don Juan exhibits the most important shot marks, three in number, produced by 300-lb. shot, two of which, with a penetration of about 4 in., are on a level with the ports, whilst the third is forward, just below the water line, having penetrated to the extent of nearly 4½ in. The

formation of these marks shows that they were caused by 9-in. rifled shot. The armor plating stood remarkably well, not a single crack being visible on the surface. . . . The only remaining shot mark of consequence is one produced by a 7-in steel projectile, which perforated the thin armor of the Ferdinand Max in a slanting direction, and remained embedded in the backing." The above extract of the official report refers only to the effects of the Italian fire on the armored portions of the Austrian ironclads, and it will be observed that even the 300-lb. Armstrong shot failed to perforate the 4½-in. armor, although this projectile is supposed to be capable of penetrating 8 in. of iron armor at a range of 500 yards.

Referring to the Battle of Lissa, the *Times* of August 31st, 1866, observes that the Austrian projectiles had very little effect on the Italian armor plates, owing chiefly to the light caliber of their guns. This does not, however, agree with the Austrian report, which says that the great loss in killed and wounded sustained by the Italian fleet was chiefly due to the fact that the Austrian projectiles struck the edges of the plates near the ports, sending a hailstorm of fragments into the interior of the vessels. No such splintering occurred with the Austrian plates." It should be observed that the Italian naval authorities then, as now, were in favor of hard and brittle armor plates of French manufacture, whilst the Austrians followed the Sheffield system of tough armor. Early in the battle the Italian ironclad, Re d'Italia, was disabled in her steering gear—which was unprotected by armor, and in this condition she was rammed and sunk by the Austrian flagship, the Ferdinand Max. The loss of the Palestro was due to a similar cause; and the Austrian ironclad Drache was, in consequence of her superior manœuvring qualities, able to pour broadside after broadside of shot and shell into her unarmored stern, until she caught fire and blew up.

The next engagement between ironclads did not occur until October 11th, 1873, when an action was fought off Cartagena, between the squadron of the insurgent chief Contreras and the Spanish Government vessels under Admiral Lobo. Contreras' flagship was the ironclad Numancia, 7,305 tons, 5-in. armor, eight 10-in. and eight 7-in. Armstrong guns; whilst the chief vessel of Admiral Lobo's squadron was the Vitoria, 7,250 tons, 5½-in. armor, eight 9-in. and three 8-in. Armstrong guns. The remaining vessels which participated in the engagement need not be enumerated, as their performances have no connection with the subject under consideration. The chief interest of the action centers in a short duel between the Vitoria and Numancia, which ended, however, by mutual consent when affairs began to assume a serious aspect. This occurred when, according to the Spanish report, "a shell from the Vitoria killed seven men on board the Numancia, including M. Moya, Vice-President of the Junta of Cartagena, and wounded eighteen others. This shell penetrated the unarmored portion of the vessel on the port side, exploded on the quarterdeck, knocked away the wheel and the head of the aft capstan, and seriously damaged the mainmast at a height of 8 ft. above the deck. One portion of the shell shivered the main yard, whilst another fragment entered the battery through the after hatch, and destroyed an iron deck beam on the port side. In this action the armored portions of the Vitoria and Numancia were struck eight and fourteen times respectively by heavy shot, but no serious damage was done, as the projectiles failed to pierce the plates.

The engagement between Her Majesty's unarmored cruisers Shah and Amethyst and the rebel Peruvian ironclad Huascar, on May 29, 1877, off the Port of Pacocha, affords further proof of the protective power of thin armor plating. The armaments of the respective vessels were composed as follows: Shah, two 9-in., sixteen 7-in., and eight 64-pounder muzzle-loading guns; Amethyst, fourteen 64-pounder shell guns; Huascar, two 9-in. muzzle-loading, and two 40-pounder and one 12-pounder breech-loading Armstrong guns. The armor-plating of the Huascar varied in thickness from 5½ in. at the turret ports to 2 in. at the bow and stern. The following is an extract from the official Peruvian report of the damage sustained by the Huascar during the above action: "The hull—A 300-lb. projectile passing through the armor plating, 3½ in. in thickness, near the side

light of the second sleeping cabin, starboard side exploded and destroyed the bulkhead, injured the tube of the cabin pump &c., besides killing one and wounding three men. Another projectile, of the same caliber, first striking the same side of the ship, and making an indenture of 3 in. in the armor plating. . . . Another, of 150 lbs., striking the same side, injured the armor plating about 1 in. in front of the foremast and 16 in. above the deck. Another shot grazed the forecastle without causing damage. Another, of 150 lbs., penetrated the armor, port side, to the extent of 2 in. . . . Another, of 300 lbs., struck the ironwork of the stern, and, passing to starboard, exploded, doing considerable destruction and wounding a sergeant of marines. . . . Turret—A 300 lb. projectile made a 3-in. indent 3 ft. from the left embrasure. . . . Different kinds of projectiles and fragments of shells destroyed the irons which served for holding the sacks, as also the wooden base on woich they rested. . . ." Nearly a hundred projectiles struck the vessel, principally about the upper works, funnel, masts, boats, &c., all of which were destroyed or seriously damaged; but the 64-pounder shells were useless against even the thinnest portion of the Huascar's armor.

The engagement in July, 1877, between the Russian auxiliary cruiser Vesta and the Turkish armored gun-boat Feth-i-Bulend, may be dismissed without further comment, for although the former vessel was badly mauled, the latter received only one shot through the funnel and another through the mainstay.

Much more serious, however, were the injuries sustained by the Peruvian ironclad Huascar in her celebrated action with the Chillian ironclads, Almirante, Cochrane and Blanco Encalada, off Punta Angamos, on October 8th, 1879. The Cochrane and Blanco Encalado mounted 6 9 in. muzzle-loading Armstrong guns each, and were protected by armor varying in thickness from 4½ in. to 9 in., exclusive of an inner skin of 1¼ in. As these vessels were built from the designs of Sir E. J. Reed, they were, of course, well protected in all vital parts by armor plating. The force of the Peruvian vessel has already been given. At 9.27 A. M. the Cochrane opened fire on the Huascar at a range of about 200 yards, and continued to engage at close quarters for about forty minutes, when the Blanco Encalada came up and joined in the action. The commander of the Cochrane, Capt. Latorre, aware of the superior manœuvring qualities of his ship, as well as of the weak points in the design of his antagonist, kept in the wake of the Huascar, directing his fire chiefly against her unarmored stern and other vulnerable portions of her hull. In the course of the fight the hull, turret, &c., of the Huascar were struck twenty times by heavy shot, ten of which perforated the armor, whilst five glanced off. The remainder of the shots took effect in the unprotected portions of the hull, principally in the stern, destroying the steering gear, and rendering the vessel unmanageable. The 5½-in. turret armor was pierced twice, the 4-in. armor once, the 3-in. armor four times, the 2-in. armor twice, and the 2-in. armor once. The projectiles which perforated the turret armor and partially disabled the guns were fired by the Cochrane at a range of only about twelve yards. A few moments later the Blanco Encalada came up, and, passing within twenty-five yards of the Huascar's stern, discharged a raking broadside into her, which killed or wounded many of her crew. The only damage sustained by the Cochrane was caused by two shells which penetrated the unarmored portion of her hull on the starboard quarter above the water-line armor and wounded ten men, whilst the Blanco Encalado received no injury whatever. Notwithstanding the terrible battering sustained by the Peruvian vessel, her engines at the close of the engagement were in perfect working order, thanks to the protection afforded them by the water-line armor. This circumstance alone is of sufficient importance to justify the demand for the utmost possible protection in our new ironclads. Had the steering gear been equally well protected, the Huascar might perhaps have effected her escape, or have succeeded in ramming the Cochrane during the first stage of the action, in which case her superior speed would have enabled her to outdistance the Blanco Encalada. Unfortunately, however, her steering gear was shot away three times, so that she was unmanageable during the greater

part of the action. Another fact worth attention is that no less than 50 per cent. of the projectiles which struck the armor plating glanced off, though in some instances the plates were only 2½ in. in thickness, whilst every shell which hit the unarmored parts of the hull penetrated into the interior of the vessel, where it exploded. The armor plates of the Huascar appear to have been of a very good quality, for though several were pierced by the heavy Chilian projectiles, not one was "wrecked," as was the case with many of the brittle French plates on the Italian vessels at Lissa.

In conclusion, the chief lessons, as regards armor, taught by the foregoing ironclad engagements may be briefly summarized as follows: (1) The details of construction, and consequently the weak points of every ironclad are known to the enemy. (2) The want of strongly-armored transverse bulkheads led to the destruction of the Palestro at Lissa, and in a great degree to the surrender of the Huascar at Punta Angamos. (3) Armor of the thinnest kind in use affords a considerable amount of protection against oblique fire, and, if penetrated, has a tendency to localize the effect of the explosion of the shell.

It must, of course, be borne in mind that all the vessels referred to above were armored with either hammered or rolled-iron plates, the best of which are about 30 per cent. inferior in resisting power to the modern compound armor, as now employed in the British, German, Russian, and most other navies. It may be observed that the maximum thickness of armor has, for the present, at least, been reached in the case of H. M. S. Inflexible, viz., 24 in., and there is now a tendency among English and French naval architects to reduce the maximum thickness to about 18 in., as demonstrated by the latest designs. There is, however, a great difference in the manner in which the weight so saved has been utilized in the respective navies, for whilst we devote the same chiefly to various arrangements and fittings of secondary importance, the French have strengthened their bulkhead and water line armor.

At present the ends of our partially-protected armor-clads are, in a sense, at the mercy of even the worst naval gun afloat, viz., the British 64-pounder. Considering the enormous size of these vessels, exceeding in some cases 10,000 tons, it is hardly an exorbitant demand to insist on the introduction of a few hundred additional tons of armor along the water line, and at other vital parts.

THE EVOLUTION OF MACHINES.

By Prof. H. S. HELE SHAW.

From the "Journal of the Society of Arts."

If we look back through the history of man, we find that his progress in civilization stands in close relation to, and, in fact, is measured by, his power over the material world around him. When we examine the means by which this power is obtained, it becomes evident that it is limited to the physical operation of changing the relative position of the materials at his disposal. At first, man was content to accomplish his purposes in order to obtain food, or for self defence, with such materials as he found in their natural state; but when a certain measure of progress had been made, and the struggle for a bare existence became less severe, he began to realize the advantages of a previous arrangement before the actual operation in view, and evidenced the possession of intellectual faculties by the design and construction of tools rather than by the mere use of them. It was the power to give materials definite form, and to effect combinations with which desired operations could be performed, that enabled further progress to be made, and so, from step to step, flint implements replacing those of bone, bronze and the easily worked metals those of flint, culminating at length in the employment of iron, the most difficult to work, but most valuable of all; man advanced slowly at first, but after a while at an increased rate, to-

wards the present mighty achievement in the industrial arts, the comprehension of only a small portion of which now demands the study of a lifetime.

For a long period man, to supply all his wants, used only such simple appliances as would, without hesitation, be called implements or tools. Gradually, however, attempts were made, with ever-increasing success, to obtain the desired result with less labor and more certainty by the construction of what might, even in their simple state, be truly called machines. Bearing in mind man's only physical mode of producing any change in the world around him, it is not hard to understand why the great extension of power and capability of making further progress may be traced to the development of machines. The relation of machine development to civilization is a subject of the greatest interest, but of vast range, and scarcely less extensive is the history of machine development itself; but they might be well brought directly, as they have so often been indirectly, before this Society, which was founded for the encouragement of arts, manufactures, and commerce. Neither of these, however, forms the direct object of this paper, but one which, it has been said, the Society has ever steadily kept in view, viz., "the application of science to practical purposes." In order to study the application of science to the development of machines, the past must be examined, so that the course of development may be seen; and though it is obviously impossible to follow in detail the growth of machinery, a few examples may be selected which will be sufficient to illustrate the fact that the growth has taken place on certain well-defined principles. It will afterwards be possible to see more clearly what is the present state of this branch of science, not only with reference to the other sciences, but also to the practical requirements of future machine development.

The history of the early machines is lost in antiquity, but it has been shown that there are strong grounds for considering the fire drill or twirling stick, first revolved between the hands of one or two operators, as one of the earliest examples of machinal motion, and that a long period must have elapsed before the introduction of continuous, instead of alternating, rotary motion. It is extremely probable that the first continuous motion was employed in connection with the grinding of corn. The use of a simple stone to pound the wheat, was followed by the use of the pestle and mortar, which, as Beckmann, in his "History of Inventions," has remarked, was probably the kind of mill possessed by every family, which Moses forbade to be taken in pawn, as being, for obvious reasons, the same thing as to take a man's life in pledge. This early mill was first worked by a female slave, then by bondsmen, and afterwards by cattle; and though at first, no doubt, only a heavy kind of pestle was used, it became evident that the end would be better and sooner accomplished if the flat cylindrical stone, with a vertical spindle, were employed, and thus arose a true example of a machine. It is evidently necessary at this point that as clear an idea as possible should be obtained of what constitutes a machine, and, therefore, without attempting to add another to the many definitions already existing, we may consider a machine to be a combination of materials arranged by man, so as to enable determinate motions to be obtained. Possibly, long before the corn mill had been advanced to the form which might entitle it to be regarded as a machine, there were many simple machines for other purposes, such as for drawing water, preparing clothing, and for agricultural purposes. These were actuated by the muscular effort of men or animals; and though the employment of the latter evinced considerable progress, it was a far greater and more important step when the forces of nature, other than muscular, were first turned to do work in machines. No doubt, the power of flowing water was the first so used, though whether for irrigation or with corn mills, or for any other purpose, it is impossible to say. Beckmann considers that corn mills were first introduced in the time of Mithridates, Julius Cæsar, and Cicero, and states that a floating mill was employed by Belisarius on the Tiber, in the year 536; but the Chinese used water-wheels for the purposes of irrigation at a very early date. The use of the more uncertain and refractory element, wind, for motive power, showed a still further advance, and though difficult to fix the exact date of the first

windmill, it has been shown by Beckmann that it is very improbable that the Romans knew of them, as the first authentic record does not occur in the classics, but in the account of a mill in France, as late as the year 1105, one in this country being mentioned in the year 1143. The greatest difficulties of all had to be overcome in bringing into direct application the molecular forces to actuate machines, but at the same time this step has been by far the most productive of results. The invention of the steam engine may truly be said to mark a new era of progress, for it has given to man the direction of almost unbounded, and at the same time perfectly controllable, machine power. On account of its importance, and also because its history is better known than that of most other machines, no better example could be chosen to illustrate the manner of machine development.

The first proposal to use the expansive force of steam was made by Hero of Alexandria, more than 2,000 years ago, but for several hundred years after, not even a reference appears to have been made to the subject. At lenglh, however, with the revival of learning, attention was directed to the properties of steam by one philosopher and another. In the 16th century, Cardan mentions the vacuum formed by the condensation of steam; and there are on record the suggestions, more or less vague, of Matthesius, Besson, Ramelli, Leonardi da Vinci, Porta, Solomon de Caus, Branca, Wilkins, and others, all belonging to what Professor Thurston, referring to the steam engine, has called the age of speculation; but the time was not ripe for practical results, and neither knowledge of scientific principles nor of the use of materials was sufficiently advanced to enable an application on more than the smallest scale, and in more than a tentative manner, to be made of these proposals. It is not till about two centuries ago that the period of application is reached, and then we find that science had progressed, the art of working iron was well established, and many machines existed. The inventor who then took up the subject and carried it to a point far beyond what it had hitherto reached, was the second Marquis of Worcester, who, in addition to the advantages already mentioned, which time and workers in other directions had brought him, possessed both wealth and influence, and was a thoughtful and studious man. This nobleman set to work upon the problem, which he prosecuted with the greatest ardor to the end of his life, and of the ultimate success of which he entertained the most exalted opinions. Yet, in spite of all this, he died poor and unsuccessful. His "water-commanding" engine, as he called his steam pump, was neither yet demanded with sufficient emphasis, nor was the practice of working materials yet sufficiently advanced to make his trial at Raglan Castle, and later still, at Vauxhall, in London, more than a partial success. Still the problem of steam power was thus brought prominently forward, and Sir Samuel Morland published, soon after, a table of volumes and corresponding pressures of steam, which, considering the date (1683), was a remarkably close approach to the best results hitherto attained. Time went on, and the miners in Cornwall were suffering from the water in their shafts; so, again, in the west of England, we find another inventor working at the question of steam. This inventor, Thomas Savery, of Devonshire, was also an educated man, being a military engineer, and it is probable that he was well acquainted with the work of the Marquis of Worcester. This is to be inferred, not only from certain statements published at the time but from the fact that his engine bears considerable resemblance to that of Worcester, at any rate as far as can be made out from marks on the walls at Raglan Castle, and the mystified description of it which was published. Now, it must be borne in mind that both these engines applied the expansive force of steam treated of by Hero, with the principle of condensation mentioned by Cardan, for forcing water in the way suggested by Porta and Solomon de Caus, but had increased the complexity of the apparatus proposed by De Caus, but the addition of a separate vessel in which the forcing was performed, and by sundry valves, which, however, greatly increased the efficiency of the engine, and, in fact, rendered it a practicable machine. Savery's engine worked to a certain extent satisfactorily, but a limit to its powers was soon reached, simply from the

imperfect materials at his command. This is made clear from the comically serious account of Desaguliers of the expenses Mr. Savery was at because he had to use hard solder instead of soft, as the latter would not withstand the heat or pressure at the joints of the boilers. It is a significant fact that one of the most successful of recent inventions, viz., the Pulsometer, is nothing more than an automatic Savery engine, which would be as useless as the engine of Savery, were it not for the present increased knowledge of the nature and properties of materials. To Denys Papin, a distinguished Frenchman, belongs the honor of suggesting, in 1690, the use of the cylinder and piston, with which the pressure of the atmosphere coul be utilized when the steam was condensed inside. That he afterwards went back from this, and endeavored so use the inferior design of Savery, in order to obtain continuous motive power by raising water for a waterwheel, does not, as it has been asserted, testify to ignorance of its superiority, and cause him to forfeit the credit for its invention. He himself said that "the principal difficulty is that of making these large cylinders," and his attempt to overcome this difficulty is proved by the present existence of a large cylinder of his construction in a court of the museum at Cassel, in Germany. The next inventor moved forward a great step, and this step was the practical application of the steam cylinder of Papin. Here, again, the west of England, where previous inventors had worked, and where the steam engine was urgently needed, supplied the inventor, in the person of Thomas Newcomen, blacksmith and ironmonger, of Dartmouth, who was assisted by John Cawley, a glazier. The former, living but fifteen miles from Savery, was probably well acquainted with his work, even if he had not been actually employed upon a portion of it, and had certainly the advantage of knowing Papin's proposal, as is evidenced by his correspondence with Dr. Hooke. The engine, under Newcomen, now assumed the form of a train of mechanism more complex, but far more efficient, and down to a certain limit, the pits were cleared of water. An accident led to the use of internal injection, and consequent increase of power in the engine. The ingenuity of a youthful attendant some time after led to its conversion into a self-acting motor, which only occurred when the boy, Humphrey Potter, to save himself the trouble of working the valves by hand devised an arrangement of strings and catches to perform this operation automatically. Beighton replaced the latter arrangement by a beam with sundry levers and tappets, and Smeaton still further improved, enlarged, and at the same time complicated the engine. It was, however, to James Watt that the greatest advance was due. The inventor began his study of the subject in 1763, at the point to which it had been brought by previous inventors, as he was led to examine the defects of the steam engine from a model of that of Newcomen at the Glasgow University. His first and greatest contribution to the problem was the separate condenser; but it is only possible to sum up all his work, and it may be said that Watt found the steam engine single-acting, and merely capable of exerting a force in one direction. He left it double-acting, capable of giving continuous rotary motion, self-regulated, vastly more economical and reliable. To attain all this, he, however, had to invent and apply much more complicated valve arrangements, packing for glands, parallel motion, governors, separate condenser, hot-well air-pump, crank, or its substitute, the sun and planet motion, and fly-wheel, not to mention a great number of mechanical details, such as extra bearings, connections, &c., for carrying these additions into effect, and for constraining the motion of the various parts, so as to make the action more certain and reliable. In reading the life of Watt, it is evident that his greatest difficulties were not in conceiving ideas, but in executing them, and that the struggle to find material and workmen represent largely his efforts during the interval of twenty years which elapsed before success rewarded his efforts. It is now just 100 years ago since Watt took out the patent for his rotative engine; and, excepting in one or two points, no improvement which has resulted in simplification can be said to have taken place. Improved machine tools have enabled the more complex parallel motion to be replaced by the guide bars and crosshead of the ordi-

nary horizontal or vertical engine; but if the condenser is often, for practical reasons, removed, this necessitates a loss of efficiency as a heat engine. On the other hand, neatness of design must not be mistaken for simplification of parts, and the compact and apparently simple modern engine may yet have reversing gear expansion valves, automatic lubricators, and a variety of appliances, which render it really more complex than the old beam engine of Watt. But to obtain an idea of the direction which progress has really taken, take the case of the engines of a first-class Atlantic steamer. The details in the annexed table of the number of parts of such have been furnished to the author through the courtesy of the builders.

TABLE SHOWING THE NUMBER OF PARTS IN THE ENGINES AND BOILERS OF A FIRST-CLASS ATLANTIC STEAMER.

Jam nuts	238
Split pins	400
Levers	37
Guard rings	108
Pins	1,144
Moving parts	100
Total number of pieces in engines	6,000
Auxiliary engines	23
Steam pipes	271
Pumping-out arrangement	172
Valves	147
Gauges	9
Lubricators, impermeators	147
Bolts	7,868
Studs	3,000
Nuts	10,407
Rivets	64,888
Boiler tubes	2,270
Condenser tubes	4,456
Boiler stays	1,582
Furnace bars	1,356
Furnaces	24

Perhaps one of the most significant items is that of the twenty-three auxiliary engines, each a separate self-regulating, self-contained, motor, supplied simply to work separate portions which, at first, used to be worked by the main engines or by hand. Consider the 764 parts made up of jam nuts, split pins, and guard rings, placed solely for extra security, not to say the 1,144 pins, many of which are for this purpose; and lastly, the enormous total of which appears to amount to 104,642 parts, each requiring separate construction, fitting and securing, and, truly, it will be said that progress does not take place in the direction of simplicity. But if the visitor is led to turn from the difficulty of even understanding this complex system, to the thought of what a marvelous achievement the design of such a machine must be, perhaps, what strikes him even more than its complexity is the perfect interdependence of the parts, and the extraordinary ease with which it is all controlled, and, in short, the wonderful unity of the machine as a whole.

The progress of the invention of the most important class of machines, viz., prime movers, has now been briefly traced, and it will be found that there are certain salient features in their development common to that of all machines.

The first of these seems to be that progress does not, as a rule, take place in the direction of simplification, but rather from simple to complex forms, accompanied by more definite, reliable, and constrained machinal motions. In proportion as the machine becomes capable of performing more extended operations, and accomplishing them by itself, requiring less human intervention—that is, becomes more automatic and self-regulating—so the parts multiply, and complexity increases. This, Professor Kennedy, in his translation of Reuleaux's work, has called an extensive and intensive growth; extensive, in decreased range of operation; and intensive, in increased internal power of action. This tendency is certainly that which is visible in past progress, and this replacing of manual effort and intervention still goes on, and is, for instance, illustrated by the enormous increase in the number of small auxiliary motors.

In the next place, it is seen that there is a conspicuous dependence upon the growth of the other arts and sciences, especially upon the knowledge of the use of materials. Again, it is clear that machines are not the product of one man's brain, but of the successive labors of many minds, and are a growth rather than a sudden creation. That this is true, even of ideas, is illustrated by the fact that nearly every successful inventor in the case of the steam engine seems to have had the benefit of knowing not only the successful, but often also the unsuccessful, attempts of previous workers, and to have even then required considerable time and labor to project further advance.

In addition to these points, there is another which comes out more clearly when a study of the lives of the inventors themselves is made, and this is that the course of invention has not been by any means continuous, but that often a retrograde movement has taken place. Machines have not only been unsuccessful because proper materials have not been forthcoming, but also because attempts at improvement have been made upon wrong principles. A striking example of this is furnished by the immense number of unsuccessful attempts to make a rotary steam engine, towards which end inventors have been (and are) apparently urged by false views of the value of simplicity in a machine. This is not only a procedure in a false direction, on purely machinal grounds which have been explained and exposed by Reuleaux, but also appears to be opposed on certain general principles to the best method of employing steam as a working agent, and the only rotary engine which at present promises to be a success has elaborate arrangements for packing purposes, rendering it anything but simple in construction.

The truth of the foregoing conclusions becomes increasingly evident upon a review of the history of other machines, whether for weapons or tools, for preparing food or clothing, for the purpose of measurement, or the communication of ideas. Only one example in each of these important classes of machines can be referred to, and that only in a word or two.

Of weapons, the most important is the fire-arm, and of this the forerunner is seen in the cross-bow, which replaced, with more perfect guiding arrangements, the simple bow and arrow. The elastic force of the bow-string was, after long use, replaced by that of the heated gases from the exploded powder; but the old matchlock was, as its name implies, a crude weapon compared with the flint-lock, and the latter was vastly more simple than the musket with percussion cap; then came the early Enfield rifle, followed by the breech-loading Snider and Martini, each more complex than its predecessor, but still simple compared with the Gattling, the earliest machine gun, which was first brought forward during the American war; this was followed by the Hotchkiss, the Lowell, the Nordenfelt, and Gardner. It was reserved for Mr. Hiram Maxim, of London, to conceive and quite recently to carry into execution a weapon which is a marvel of automatic action, and illustrates in a remarkable manner the tendency towards that intensive development of machines already referred to. This gun actually performs all the functions of carrying the cartridge to its place, of locking it in, cocking, firing, withdrawing the shell of the cartridge, and ejecting it, and this not by the force of human action, but simply by the force of its own recoil, which has only hitherto produced an injurious shock upon the supporting frame. Yet the external appearance of this gun is remarkably simple, and it has but one barrel; but if anyone thinks its construction is really a step in the direction of simplicity, let them go through the process of understanding its action from written description, aided merely with diagrams. Yet, in the history of guns, the progress has not always been in the forward direction; the big breech-loading guns first introduced were, after a while discarded, and a return made to muzzle-loaders; but this was simply because of the difficulties of safe and reliable construction, a matter which the progress of knowledge has in time enabled to be satisfactorily accomplished.

In the case of tools, the early hand tools preceded the primitive lathe, in which, when two operators were not required, the two hands of the worker were supplemented by the assistance of one foot, his big toe being also brought into requisition as he sat on the ground in front of his work. The lathe, with a simple hand-rest, was the factotum of the early machinist; by its means his boring, turning, and drilling was at first done, but by degrees the slide rest and screw-cutting gear, speed cones and surfacing arrangements, pulleys, and various other appliances, were gradually introduced. The increased complexity is not only seen in the particular machine in question, but in the variety of special tools derived from it, such as meet the eye of the visitor in vast array in such a place as, for instance, the machine department of the locomotive works at Swindon. There are seen

special turning, boring. surfacing, drilling, screwing, facing, polishing, grinding, centering, and other machines, all to do the special work of the early lathe, and of many of these numerous varieties exist, often differing apparently in external appearance. These are only a small portion of metal-working machines, and equally striking examples of tools for working wood and other materials might be taken. Special tools, like the steam hammer, have a history which testifies to the nature and mode of progress, not less than the lives of Maudslay, Whitworth, Nasmyth, and other great tool makers. The progress of the hammer, from the first stone weapon to the tilt hammer, and then to the great step of the steam hammer by Nasmyth, which no one would take up in this country even after its application, at first unknown to him, at the Creusot Works in France, because "it was not likely to be required," its improvement by Condie, and the limit of its powers, not by any inability to construct still larger forms, but for reasons which render hydraulic pressure upon huge masses of metal a superior kind of action, all of this being in accordance with the views previously stated.

In connection with machines for supplying and preparing food, there might be taken the whole class of agricultural machinery, besides a large number of special machines for various purposes. The early history of corn mills has already been referred to, and the gradually increasing number of appliances which were introduced into the water-mill, increasing, to a certain extent with the introduction of the windmill, and in a still greater degree with the modern steam flour mill, might be found undeniable increase of complexity. But if the system of low grinding with the simple circular stone has itself grown more complex, what might be said of the system of high grinding (invented to deal with the hard grains) as practiced in Austria and America, where the flour is, by a complex series of mechanical processes, divided into as many as ten or twelve different qualities, or of the various refinement for cleaning and separating the grain for grinding, for sifting or dressing, and lastly, for purifying. A high authority on the subject, Mr. Proctor Baker, says, "One rule must predominate over all other considerations, viz., that the material in the process of manufacture must not require to be moved by hand labor, at any stage, from its reception into the mill until it is finally packed in the bags in which it is to be delivered to the consumer." But, in this case, many millers have found, to their cost, that there is a very close connection between the machine and the work required from it, and that costly and expensive plant does not ensure the best results, if the correct requirements of the case are overlooked. The tendency is to make the process more independent of external intervention from manual sources.

Coming now to the important class of machinery employed in connection with clothing, the history of machines for working either cotton, wool, hemp or flax, all tell the same tale of gradual improvement and more intensive forms of construction; but instead of any of these, which have really become systems of machines, a single machine of more modern introduction may be taken. The sewing machine is universally known and employed, and is commonly supposed to have been invented, perfected, and brought into general use almost at once.

This is, however, very far from the case, and a writer in Knight's "Dictionary of Mechanics" thus describes its invention:

"The earliest machine first used the needle and needleful of thread in making a running stitch. Then the eye was placed in the middle of the needle, which was sharpened at both ends, to save turning it about when returning it, the needle being pushed and drawn by steel fingers on each side of the goods. The invention was yet an implicit copying of human manipulation, and the next step merely shifted the mode from the stitch of the seamstress to that of the tambour worker. The needle was passed through the goods and returned, leaving a loop, which was to be detained so as to be entered by the needle at its next descent, leaving another loop, and so on. A modification is mentioned of a crotchet hook; . . . . but a man of mark will find a new departure. He must devise new modes of procedure adapted to the needs of the new steel man who is

automatic but unskillful, and one of whose principal requirements is continuity of motion. . . . . The new elements were not invented all at once. One of the most important was overlooked for fifty years after it had been patented. Another was invented, made, and exhibited, and then slept a profound sleep of twelve years; another was invented and patented, but was in a useless shape, and lay dormant until really valuable inventions were made, when it arose and claimed them as mere adaptations. There is no important machine for sewing fabrics now manufactured that does not use all of the three elements mentioned—the continuous thread, the eye-pointed needle, and the continuous feed; but the former two of these had been in existence for sixty and twenty years respectively before they were united to the latter, which, coming in the fruition of time, was more quickly recognized as a necessity."

Yet, curiously enough, this clear account is prefaced by the following words:

"The growth of invention is in the direction of simplicity; but it is necessary, in the first place, to conceive needs, and then to follow a host of temporary expedients—mere patchwork, as it afterwards appears. In the course of time rises a reorganizer, who proposes to devise means adequate to meet the changed conditions which supervene, when a machine is called upon to take the place of the human operator."

Now, from what was before quoted, it is clear that the sewing machine really became more complete in proportion as it became more efficient; and indeed, the last lines show that the writer, to a certain extent, recognizes this fact; so that this is an evident case of the common error of confusing the idea of apparent simplicity from improved external design, with the real simplicity of essential parts.

Time does not permit of any account to be given of the growth of that typical instrument of measurement, the clock, even one stage of which, viz., the invention of the chronometer by John Harrison, the history of which has been recently so ably told by Dr. Smiles in his "Invention and Industry," is so full of instruction. Neither can machines for the communication of ideas be more than briefly noticed by a reference to the also typical printing machine. Blocks of burnt clay, stone and wood, had been used from the earliest times, and from the handles upon those in the British Museum, which were in use by the Romans before the Christian era, the mode of operation is evident. It is not very clear when the first printing press was invented, but the early screw press was evidently in use for a long time prior to the year 1620, when Blaew, of Amsterdam, introduced the traveling bed, the lever-screw for depressing the platten, and the spring for raising it. Only slight modifications were made until the invention by Lord Stanhope, at the end of the 18th century, of the toggle joint press. In 1790, Nicholson invented the first cylinder machine; in 1811, Koenig (whose history is also as well told by Dr. Smiles) set the first steam-printing press to work, and the *Times* of November the 29th, 1814, was the first instance of a newspaper printed by steam. The course of invention has since then moved onwards, and anyone who has watched an edition of the *Times* being printed off will be quite prepared to admit with, perhaps, as much emphasis, the marvelous definiteness and certainty of action of the present machine, and they will also admit the fact that simplicity is not the most striking and obvious feature.

The foregoing examples will suffice to make it clear that machine development has followed the path of progress from simplicity to complexity, and at the same time from indefiniteness and uncertainty of results to definiteness and certainty; also that this has been accompanied by the tendency to multiply different special parts, or even separate special machines, as in a machine workshop or mill, but, at the same time, to render the machine or machine system more and more one compact and integral whole. But this is exactly following what is known as the law of evolution. This law, long ago applied by Herbert Spencer in his first principles to social progress generally, is defined by him thus: "*Evolution is a change from an indefinite incoherent homogeneity to a definite coherent heterogeneity, through continuous differentiations and integrations.*" Perhaps

the thought may occur to someone present that evolution might with profit hold with regard to this mode of statement of the law itself, but it is evident that its application to machines is fully justified. But the law is borne out in details, notably by the fact that progress, as has been shown in several cases, has not been continuous and uninterrupted, for that some time a retrograde movement has taken place, and sometimes the environment, in other words, the state of other arts and sciences, has required modification for any further change at all to be made. Thus again may be applied to machine development Herbert Spencer's statement in reference to progress generally, that "throughout that re-arrangement of parts which constitutes evolution, we must nowhere expect to see the change from one position to another affected by continuous movement in the same direction. We shall everywhere find a periodicity of action and re-action, backward and forward motion, of which progress is a differential result." Hence there appears to be abundant grounds for taking, as the expression of an important truth, the idea conveyed by the title "The Evolution of Machines."

All that has been hitherto done in this paper is to consider the actual growth of the machine itself, and the ideas which have guided inventors have been only alluded to incidentally. It is, however, the latter subject, viz., the line of thought followed by the inventor, which really forms the object of our investigation and to which the study of the growth of machines was only a preliminary but necessary step.

The points concerning the inventor which appear to have been brought out, are:

1. The increasing complexity of the machines which it is his task to improve upon, and the already highly developed state in which he finds them. This fact necessitates careful preliminary study of the subject if—as was, for instance, the case of James Watt—he would start level with the age in which he lives, and from that stage of development to which other workers had brought the problem he essays to carry to a still more complete solution.

2. The successful inventor is not, as a rule, the entirely original genius commonly supposed, but has depended upon others for many suggestions and experimental results.

3. That however sound may be the ideas of an inventor, he depends both upon the progress of the other arts for its successful carrying out, and upon the demands of the age for its successful introduction and application.

It will be well to consider briefly the modes of thought and precedure of inventors, and without pretending to do more than mention typical cases, it may be said that there is, first, the man who, knowing little of what has previously been done, upon conceiving an idea, at once endeavors to put it into a practical form with such rude materials as he may be able to command, and after many failures, even supposing that he succeeds, probably finds that his idea is either of no practical value or has been invented many times before. Next there is the man who, with little experience or knowledge of principles, yet has the wisdom to spend time in a vigorous preliminary effort to ascertain what has already been done, and the effort will need to be vigorous if we search the Patent-office records in their present state; but even though ill-equipped with appliances, he at any rate starts with a knowledge of previous attempts, and does not waste time in re-invention. Lastly, there is the man who, either trained in science, or, what in the present case amounts to the same thing, has correct views of the principles which concern his end, starts with a full knowledge of the special machine, as far as it has hitherto been developed, and who has command, either by means of good workmen or by his own personal knowledge and skill, of the best appliances of the existing state of the arts. Though it has been said that great inventors are born and not made, yet, however naturally gifted the inventor of the first class may be, it will take a long and weary struggle to give him anything like a chance of doing what one of the last class may at once accomplish. In spite, however, of this, it will be found that the difference between these invetnors, however great it may appear, is really one of degree, and that the general mode by which the result has been arrived at is, as far as it can be discovered, practically the same. Though the last may

have used one or more known sciences, it was, to a certain extent, by a process unknown to himself that even he arrived at the result. It was more or less a groping in the dark—in one case it was almost all darkness—but on some of the steps in the other the light of knowledge was flashed. Thus, as Reuleaux has pointed out, there arises that reverence for the inventor which is greatly due to the fact that he has succeeded by a process which is unintelligible even to himself. And what has been said of inventors generally may, with equal truth, be said of the every-day practice in a drawing office, of designing machines, even with only slight variation to previous forms. But this is clearly not science but art, the art partly natural, partly acquired, of putting together knowledge, and of applying the results of science. It may, therefore, not unnaturally be asked—Why is not a distinct science of machines directly applied to the problem to be solved?

In order to answer this question, let us briefly glance at the history of the study of machines, and particularly at its present state. It was not to be expected that a science of machines would be originated before machines had themselves reached a certain stage of development; but that after it had been originated it would itself follow, as other sciences have done, the law of evolution. Such has been the case with the study of machines, which at first was merely descriptive; but as machines multiplied, some classification became necessary, and attempts were made to effect this. Reuleaux, in his sketch of science, considers Leupold to be the first to separate (in 1724) single mechanisms, but that nothing like a system was formed until quite the end of the 18th century; he proceeds to review the various attempts to found a science of machines upon fundamental principles, but it must here suffice to say that though each worker has taken a part in the progress of science, yet no one succeeded in founding a system which has had a practical application, and we therefore come at once to the system of Professor Reuleaux himself.

Rather more than ten years ago, the "Theoretische Kinematik" of Reuleaux was published in Germany, and about two years after was translated into English, and edited by Professor A. B. W. Kennedy, who, for excellent reasons, adopted for it the title of "The Kinematics of Machinery." The kinematics of machinery may be considered as the science of the motion of constrained bodies, regarded specially from the machinal point of view. Bearing in mind what was said at the commencement of the lecture, no arguments are needed to show why this must, to a great extent, be regarded as the science of machines; for it is clear that if the only physical mode of operation by which man can act is to effect a change in the relative position of matter, this not only shows, as there explained, the reason of the importance of machines, but also points to the science of machine motions as the branch of greatest importance. This it does by making it evident that the object of a machine is to effect a desired definite movement or motion of some portion of matter. The practical bearing of this consideration is forcibly illustrated by Reuleaux's ultimate division of all machinal arrangements into place-changing machines, as, for instance, locomotives, cranes, clocks, &c.; and form-changing machines, as, for instance, corn-rolling—or saw-mills, lathes, paper-bag machines, &c.

The deep and far-reaching principle upon which the system of Reuleaux is based, is that of the mutual contact of the moving parts of a machine. In all cases these parts must have the property of mutual envelopment, if their relative motion is to be constrained and definite; and this correspondence or pairing, which is an essential feature of the machine, leads to the statement that a machine consists solely of bodies which thus correspond pairwise reciprocally. Pairs join together links, and links form a chain, and a chain is a machine. It is by the combination of chains that any and every machine, no matter how complex, is formed. This method of viewing the machine problem leads to a matter of the greatest importance, viz., the construction of a "notation" for machines upon scientific principles. Previous attempts to introduce symbolic representation of machine parts had only been partially successful, even for trains of wheelwork, while for general purposes they had been eminently unsatisfactory. The

value of Reuleaux's system is shown by the concise way in which it represents the remarkable results of his analysis of machines, and puts the otherwise impossible task of understanding at any rate the leading features of all the various machines, within measurable distance of being grasped by the human intellect. But more than this is done. After analyzing a large number of machines, Reuleaux concludes by what must be regarded as the first effort to found a system of kinematic synthesis, or building up of machines. The problem of kinematic synthesis is divided by him into direct and indirect, each of these divisions being again subdivided into general and special. General direct synthesis should give immediately the mechanisms to effect a given place or form change; but it is shown, from practical reasons, that useful results from this cannot be expected. Special direct synthesis would furnish a pair of elements suited to effect the above result, but neither can this method give results of practical value.

General indirect synthesis should give beforehand the solution of all machine kinematic problems in advance. This is obviously an enormous requirement; but it is shown that there are six principal chains or mechanisms upon which most machines are based, and these Reuleaux examined. Special indirect synthesis, however, does lead to really practical results, and the whole possible number of pairs are determined and arranged in twenty-one orders. The author of this system does not, however, recommend the special study of this branch of the subject, but rather that machines should be treated under applied kinematics generally, and arranged according to their practical application. Indeed, beautiful and interesting as this part of the subject is, it must be said that it appears to be the least satisfactory portion of Reuleaux's great work, and this, with our present object in view, is certainly disappointing. Perhaps the reason for this is to be found in the fact that the motion to be obtained, though it truly forms the practical object he sought, and therefore makes the branch of the subject already considered the most important, can, after all, only be carried into actual operation by practical means. In short, the definite and constrained motions sought after can only be obtained by employing suitable materials of the necessary strength. The progress of knowledge concerning materials has already been shown to have always borne an intimate relation to the progress of machines, and obviously upon the scientific application of this knowledge must further advance depend. Reuleaux, it is true, introduces the idea not merely of rigid solid bodies and flexible solid bodies (as belts, cords, &c.), as Willis had done, but also fully considers, from a kinematic point of view, the machinal properties of liquids and gases, and one of the most important and interesting parts of his work deals with this subject. This is a great advance, but still there is an immense field untouched by this system, as, for instance, the nature of the best forms to be given to the links, or, more important still, the actual effects from the contact between different materials, the nature of which very often entirely decides the fate of a new machine. On these points our knowledge is yet far from complete. Thus take the modification of the time-honored laws of friction when applied to lubricants, resulting from the recent experiments by the Committee of the Institution of Mechanical Engineers, or consider how much is even now known of rolling friction, and its exact effect on frictional contact. Knowledge of materials is increasing with the increasing use of testing machines of all kinds, but unless the unlikely event happens of very great discoveries in the preparation of materials continuing to be made, some more compact and final arrangement of the present knowledge in connection with the science of machine development should be possible. In addition to mere motion and the question of materials, the scientific application of the principles upon which the forces of nature can be made to overcome the resistance to the required motions in the machine, have also frequently to be considered by the inventor. These three branches of knowledge now considered, viz., motion in machines, the nature and strength of materials, and the forces which are required, are studied in this country under the heads of Mechanism, Machine Design, and Prime Movers, and collectively represent the present state

of the science of machines. It must, therefore, be admitted that at present no definite synthetical science exists which can be directly applied to the "evolution of machines."

When the difficulties in the way of such a science are realized, it may, perhaps, be doubted if its ultimate evolution be possible. Such a doubt might, not many years ago, have been well felt about chemistry, and what chemist would have been led by the highest flight of imagination to anticipate a tithe of the results which have ensued from the introduction of chemical notation, applied to carefully collected facts. Organic chemistry, before that event, had not an existence, and, to say nothing of inorganic chemistry, what human brain could carry all the facts necessary for further investigation, if a descriptive notation did not render classification upon scientific principles possible? But, beyond this, the most important results have been in the direction of synthesis; and no one would venture to assert that the building up of such complex bodies as indigo, benzene, or even of acetic acid, would, in all probability, ever have been made without the aid of a scientific notation. A complete synthetical science of machines appears, however, to present, in some respects, greater difficulties than even those in the corresponding branch of chemistry. Without attempting to institute too close a comparison, it may be said that in the latter, the object in view is the building-up of a body, of which the parts are known by analysis, but not their grouping or arrangement; the nature of these groups, and the mode of re-forming them, have to be determined by careful reasoning and experiment. In the machine problem, a result has to be obtained, the necessary parts required for which, as well as their grouping or arrangement, have to be determined. And this we have, in addition to mere synthesis—the selection and determination of these parts in the form of pairs and links, as well as their combination into definite groups or arrangements, in order to form complete chains, or series of chains, necessary for the constitution of the complete machine. But, beyond even this, there is the selection and preparation of suitable materials with which to construct these parts, and this has been shown to form in itself a matter of no little importance. In spite of these difficulties, there appears to be no reason why, at any rate, a great advance should not be made on the present methods of machine evolution, for it must be pointed out that, in one respect, the machine problem is vastly more simple than the chemical, in that we can combine at will machine parts, and understand their mode of combination; whereas we have no certain physical conception of the nature of the molecular combinations which result in the production of such different external forms. Even in its present state, however, much might be done by a more systematic teaching in this country of the science of machines as it at present exists. At this point, however, the vast results already attained in the direction of machine development may occur to you, and at the same time, the nature of the methods—or, rather, want of methods—of previous workers; and the doubt may arise as to the need of such an arduous search for a more scientific treatment of the question, and such a careful preliminary study of the subject. It will, therefore, be well, in conclusion, to briefly consider this question.

The respectful admiration with which a successful inventor is regarded has been already alluded to, and one, indeed perhaps the chief reason, has been mentioned; but there is another, and perhaps equally significant one, which is that the lot of the large majority of inventors is simply failure. The statistics of the Patent-office furnish striking testimony to the testimony of this. The diagram on the wall represents the curves obtained by plotting the number of applications in each year for patents, since the important act of 1852. The years are given along the horizontal scale, and the number of patents applied for and proceeded with for 3, 7 and 14 years, are shown by the corresponding height on the vertical scale, so as to give the different curves. The curves are partly taken from the Commissioners' Report of 1880, and filled in, as far as possible, up to the present date from data kindly supplied by Mr. Lloyd Wise. The point to be first observed is the large number of applications not proceeded with, and the great drop in the number

carried on after three years; lastly, how small a portion survive the seven years' period. Now, the greater number of these patents are for machines or mechanical devices, and it may be asked, why all this failure? which, however, large as it is, only illustrates a small proportion of the non-success of workers at new and improved machines. Some small portion of it is, no doubt, due to want of funds to carry on the work, but chiefly it arises from either a discovery of want of novelty, or of impracticability in successful execution of working, or of improved methods of carrying the idea into operation; that is to say, from (1) ignorance of previous achievements, (2) or of principles, (3) or of practical details.

1. Every day makes it harder to keep abreast with the multiplication of machines; thus, take one book, and that not the largest on the subject, viz., Knight's "Dictionary of Mechanics," in which are nearly 4,000 pages and 10,000 engravings of inventions which are, or have been, in actual use, but this does not represent a tithe of those essayed and found to fail. Nearly a century ago, Beckmann, writing of the invention of a machine for sowing seed, remarked, "The case with Laua (the inventor) was the same as with many ingenious men who possess great powers of invention, as they never read, but only think, they are unacquainted with what others have done before them, and therefore consider every idea which comes into their minds as a new one;" and thus, as Sir John Hawkshaw, in his address as President of the British Association, remarked, "Many a patient investigator has puzzled his brain in trying to solve a problem which had yielded to a more fortunate laborer in the field some centuries before." But if Beckmann's saying had force in his day, when the number of machines was so few, what should be the reading necessary at the present time? The truth is, that in the present state of the literature of the subject, the reading necessary to determine what has been previously done, in the case of any one special class of machines, or very often of a single machine, is well nigh appalling, and anyone, for instance, who had attempted a weary search among the patent records, would testify to the urgent need of a more scientific treatment and classification. The work of indexing at present being carried on in our Patent-office will prove a great boon to inventors, but a great deal more might result if that classification could be made on really fundamental principles, such as have been proposed and fruitfully applied by Reuleaux.

2. Ignorance of principles is another cause of failure. Correct principles are not by any means of necessity intuitively grasped, an instance of which fact is given in the case of George Stephenson, than whom a clearer-headed man or better mechanic, perhaps, never lived, but who, at one period of his life, spent no little time in the attempt to make a perpetual motion machine. Even those principles which, as the result of long experience, have been handed down in the form of apparently simple laws, require long and careful study for their realization. How often does an inventor, possessed by one idea, go round and round in a circle in the endeavor to carry it into practice, and, like a mouse in a cage, return, after a cycle of attempts, to the original designs, sometimes quite unconscious of the fact, and sometimes with a faint hope that he has not yet tried it in quite the correct way. This may lead, and sometimes does lead, to discovery and a successful invention, but is far more often the mere pursuit after an *ignis fatuus* in the shape of an impracticable scheme. A better acquaintance with principles might prevent this, and it needs no argument to prove the advantage to the inventor of being able to clearly realize the main principles upon which he intends to construct a machine, such as the employment of a given chain, and the mere variations in the mode of carrying it out by the alteration, such as by inversion or expansion, of certain pairs of elements of which it is formed.

3. Again, there is an ignorance of practical details, as, for instance, of the most suitable materials and mode of employing them. The inventor on these points often calls to his aid the practical man, and, if his idea is correct in principle, he may thus be enabled to carry it into execution. But there is an unsatisfactory aspect to even this course, for it may be that the principle, though correct in itself, requires for its successful car-

rying out conditions which the so-called practical man is not very likely to realize, at any rate at first. This is, in fact, the important subject of the limits imposed by the materials available, and this becomes in itself a scientific question. Take, as an example, the case of heat engines. In the case of the hot-air engine, it may be said that precisely the same chief difficulties exist at the present day which led to the rejection of the Stirling engine some time after its trial in 1845, at the Dundee Foundry. The limit of power was due to the limit at which the vessels could be heated; yet, up to the present time, inventors continue to try and increase the power of this, in many respects, admirable motor, by different small and minor alterations, and yet have only at their command, and so can only employ, the same materials as were used forty years ago. The late lamented Chairman of the Council of this Society expressed, some three years ago, as his opinion, that the gas engine was in the same condition as was the steam engine at the time of Newcomen, and that the necessary cooling of the cylinder caused a loss of from one-half to two-thirds of the total heat generated; but at present this heat still continues to be thrown away, notwithstanding the labors of innumerable inventors, simply because of the working limit of temperature with the available materials in use. To this cause also must be traced the comparatively small increase in the efficiency of the steam engine since the time of Watt. But while, on one hand, the fact has to be clearly realized by inventors that the limits of temperature, strength, and the velocities of surface contact are known and have to be reached, yet the possibilities opened to them by an advance, such as the employment of the electric current or of the use of steel, affords fresh ground for further study and advance. The comprehension, therefore, of what is practicable and what is not becomes of the highest importance.

Enough has been said to show that a more careful treatment of the whole science of machines would be justified from the point of view of the individual inventor. The great advance in scientific instruction in the country, notably under the auspices of the Science and Art Department, but also in schools and colleges, has prepared the way for this. But still it is not to be expected that all inventors will, in the future, be at the pains to acquire the information of real value to them, or even in some cases be more patient of salutary advice than formerly, from the outsider who sees the reason of the futile attempt to escape from the cage of a leading idea. Here, however, a law which has special application to biological development holds rigidly, both with respect to machines and their inventors, and a process of natural selection assuredly results in the survival of the fittest.

There are other grounds for asserting that machine science should be carried to a more complete state, and that it should be more applied than at present, and these, did time permit, might be profitably discussed. Thus, it may be found that, just as from the International Exhibition of 1851, we had to realize the unpleasant fact of Continental superiority in the production of many machines, and were led to make the great changes of the Patent law of 1852, so in the forthcoming International Exhibition it may be made clear that the more systematic and long-continued instruction in machine science abroad has led to results which may stimulate its more careful treatment in this country. Or, again, much might be said about the present basis and grounds of the examination of patents in the Patent office. From the curves of applications for patents already shown, it is evident that though the number has been steadily rising since 1852, yet an extraordinary increase has taken place since first January last year, when the new Patent law came into force, and up to the present date the number promises to be nearly as great for this year. There is little doubt but that this is greatly owing to the reduction in fees during the earlier stages, though it remains to be seen what proportion will be carried through the periods of seven and fourteen years, for which the fees remain the same. It may, however, be safely predicted that this great rise will contain even a smaller proportion of surviving patents, and it will be admitted that Sir Frederick Bramwell had good grounds for not wishing the fees to be so reduced as to lead to an abnormal increase of ill-considered schemes. It is certain

that, even at present, the difficulty of deciding whether an invention is new will be much increased, and will continue to increase, unless some more scientific mode is adopted of determining what really constitutes novelty in an invention. The evils of the present want of a universally-recognized scientific basis of examination is even more strongly felt in applications for patents in various foreign countries, as many a luckless patentee knows to his cost.

To sum up the results in this paper: An attempt has been made to show that machine development has followed a definite course, and has obeyed the general law of progress; that the science of machines is likewise following this law, but at present must be regarded as in an inchoate stage; that there are strong grounds for its increased study and application in this country, and, at the same time, for its further development.

In conclusion, it may be said, the growth of knowledge generally has resulted in laws which have not only brought the numberless facts within our grasp, but have led to further progress. We may not agree with Buckle in his fundamental principle as applied to the history of civilization, which is, that "the totality of human actions is governed by the totality of human knowledge;" but we must admit that the totality of human inventions is so governed. Thus we feel that, in this case, the words of Hermann Kopp, in speaking of the science of chemistry, and quoted by Professor Schorlemmer, apply with force:

"The alchemists worked in vain; it is not in our power to appropriate to ourselves the experiences and results which the future alone can bring. But in a certain sense we are indeed enabled to prolong our life backwards into the past, by appropriating the experiences of those who were before us, and by becoming acquainted with their views as thoroughly as if we had been their contemporaries. The means of doing this is also an elixir of life."

Thus in yet one more respect we have a feature of evolution apparent. Biologists tell us that each animal lives in one short life the whole course of development of its species. So must the inventor live through the whole progress of the special machine he seeks to improve. He may do this by repeating the painful experiences of former workers, or he may avail himself of those lessons which their failures and successes have taught. We should think strangely of a would-be explorer who refused to reach the real scene of his labors by the track which, imperfect and toilsome though it might be, had, in its mere discovery, cost the life labor of many previous travelers; and who, neglecting to avail himself of the previous experience of others, preferred to fight his way to the same end through thicket and jungle. We should scarcely expect him to ever attain that point where his real labors should commence. This must we think, too, of the inventor who, slighting the history of the past, and omitting to benefit by the experiences of the previous workers, essays to take even a humble share in the "Evolution of Machines."

DISCUSSION.

Professor Perry said one was naturally struck on going on board a large ship like the Devastation with the idea that machines were getting exceedingly complicated, and as it was now about 15 or 16 years since he had made such a visit, he had no doubt that still more complicated machines were in use now. Still, on carefully examining the machinery, he found he could understand it. For instance, there were a number of fans for ventilating the ship, and collectively they made a complicated looking piece of apparatus, though the parts were simple enough. If he differed in opinion from Professor Shaw, it was on account of the different meaning which he attached to the word "complicated." To consider the culminating example of the engines of the Atlantic liner giving, say, 10,000 horse-power to the propeller shaft. Now, consider how Watt, 100 years ago, would have given this horse-power to a shaft. If he had been asked to do this, he could have done it, and he would probably have put in 100 of his engines, filling the ship with machinery. It was also quite within his powers to have arrangements which would enable all his 100 engines to stop or reverse at the same time, and instead of the 100,000 parts of existing engines, he would probably have used in all his engines and boilers ten times the total

number of rivets and nuts and other pieces. In fact, to give 10,000 horse-power to a shaft in Watt's days would have needed machinery much more complicated than the machinery in use at the present day. Professor Perry contended that it was on account of the complicated nature of the known machinery necessary, that large steamships were not driven across the Atlantic sixty years ago, and that it was the simplification of construction of steam engines which had enabled huge Atlantic liners to be workable. Although, no doubt, there was a law of evolution in machinery, it would be rather rash to conclude that they knew what that law was. It was all very well to tell inventors of gas-engines that there was no hope of getting much greater efficiency than had yet been attained, but they knew that a great deal had been done in the past, and he believed that if people went on hammering their heads long enough against this wall of the materials not being useable at very high temperatures, they would discover new materials, or some way of getting round the difficulty. It was said that by Taylor's theorem, if you knew the complete motion of a particle, its exact position in space, its velocity, acceleration, and a variety of other things, all included in an exact knowledge of its present state, you could prophecy the position of that particle millions of years hence, and tell what its condition was millions of years ago; and it semed to follow certainly, from the theorem, that you could do so. In the same way, if they knew the law of the evolution of machines, as some higher beings might know it, they might be able to say what machines would come to a few million years hence. But they did not know the law of the evolution of machines; they knew very little of it. The country of Erehwon would probably be known to most of the audience who could spell backwards, and there the people thought they knew the law of the evolution of machines exceedingly well; they saw machines getting more and more powerful, and men getting more and more the slaves of machines, which were becoming more and more automatic, and more and more capable of self-production, so that after a time they feared there would be no room left for human beings on earth, except as parasites, and so they broke up the machines, and when the great traveler who discovered the country visited them, he found they were using very common implements, the fields produced very little wheat, and they were not surrounded with very many comforts. All this evil proceeded from their having the notion that they knew a great deal about the evolution of machines.

Professor Hughes, F.R.S., thought all must agree in the main points of the theory which Professor Shaw had put forward, because he had shown the evolution of these machines, but he had not shown the failures, and he could not say that these stepping stones showed exactly the law. It was certainly a great thing to know what had been done, but great things had been done by men who really knew nothing of what had been done, and which never would have been done had they known it. Take for instance the telephone, all scientific men would have pronounced it to be perfectly impossible; and if Professor Bell had passed his life in studying the science of telegraphy, he never would have invented it. There was, therefore, a good deal to be said on both sides of the question.

Mr. Hiram Maxim then described at some length the construction, and showed the mode of working his patent gun. He said the complication to which the reader of the paper had alluded was not a necessary part of the gun; it might have been made to load and fire itself without so much complication; but these complications were introduced in order to allow of the magazine for the cartridges being placed under the gun instead of over it, where it was more exposed, and of its continuing to fire automatically with no attention beyond that of one man who directed the fire. Some other guns required two men to put the cartridges in at the top, and one to turn the crank for firing, and another to turn the gun about, which made the motion very slow, the cartridges falling into their place by the action of gravity. In this gun they were arranged in a belt from which they were taken one by one, and a belt might be made to hold 2,000 if necessary. The speed was adjustable by the trigger, and could be made as high as 600 per minute. The gun could be adjusted so as to have a horizontal fixed range between two points, and thus, if works destroyed in

the day were repaired by the enemy in the night, the bearings and levels could be taken in the day time, and fixed, and at night the gun could be kept firing between these two points all night, by simply a boy to move it slowly from side to side; and he should not be surprised to find that the boy, like the one they had heard of, had devised some plan for making the gun do this automatically. There was such beautiful adjustment in every direction, that you could easily write your name on a screen with it. Having described the means by which the recoil from each shot was utilized to extract the empty cartridge case, Mr. Maxim concluded by saying that when once put into work, the gun would go on firing, if desired, until the man who paid for the cartridges was in a hopeless state of bankruptcy.

The Chairman, Sir Frederick Bramwell, said he gathered from the paper that Mr. Hele Shaw's notion was that the evolution of machinery tended to complexity, and that did not seem very unnatural. As time went on, persons found that devices which they thought would not work, and would get out of order, would work, and could be trusted; they then thought if they could trust one, they could trust two, and so they used two instead of one, with the result that certain functions which had formerly been performed by humanity might be performed by apparatus. Therefore, owing to improvements not only in material, but also in workmanship, machinery became more trustworthy, and, as a consequence, more complicated, and greater benefits were derived from it. He had been much interested in the two early lathes which had been shown, one where the operator held the tool down with his toe, as he had often seen done in Cairo, and the other, the old pole-lathe, the implement on which he first learned to turn. He was sorry to hear Mr. Shaw treat the attempt to make a rotary steam-engine as a retrograde movement. In his judgment it was a reproach to mechanics that they had to begin with a reciprocating movement when they wanted to end with a rotative one; and he could not help thinking that those who, time after time, attempted to solve this problem were deserving of their thanks. He agreed very much with Professor Perry, that there was a good deal to be said on both sides of the question whether inventors ought to know everything which had gone before; and with Professor Hughes, that no one who had been familiar with the science of electricity would ever have dared to think about the telephone. Again, to call to mind the wonderful boot-sewing machine of Blake, which it was agreed on all hands the inventor never would have invented had he known anything about boot-making. No doubt there was considerable danger, when a man studied all that had gone before, that his mind would get into a groove, and thus he would not make really substantive inventions. When speaking on the Patent laws, he had often pointed out that a very favorite suggestion of the opponents of such laws, that there was no need for them because the inventor would be rewarded by making the thing he invented and selling it, was a fallacy, inasmuch as very often the man who had made substantive inventions had been wholly unconnected with the trade to which they referred, and was, therefore, incapable of competing commercially with those in the trade. This being so, he was inclined to doubt the soundness of the suggestion that all persons, before beginning an invention, should know everything that had gone before. In the conclusion of the paper, comment was made on the large number of patents applied for, in comparison with those which were completed. He, for one, was very glad to see that difference, because it represented the value which they had contended so much for in all these patent questions—the time of the provisional protection giving the patentee time to experiment and make inquiry. By that means he found out that he was wrong, that the thing would not do, that it was not novel, or that for some other reason the thing could not be gone on with, and in that way the full benefit was secured, both to the inventor and the public. He looked on the number of abandoned patents as by no means a thing to be deplored, but as an evidence of the care and forethought exercised by inventors before going on to complete their patents.

Professor Hele Shaw said the first three speakers had almost entirely cor-

roborated, at any rate, the tenor of his remarks. He had not been able to develop his ideas completely, for when he came to write the paper, he found that the subject really required a book, and he had to leave off where he should have liked to begin. He believed the general theory of evolution did hold good with regard to machines, and when Professor Perry said he did at last understand the machinery of a large ship, what more striking proof of the truth of his views could be desired. Again, the same thing occurred when Mr. Maxim explained why he had been led to complicate his gun, namely, to make it a more efficient machine. When he used the term complexity, it did not necessarily mean the addition of parts which would get out of order, but that with the progress and development of the manufacturer's arts, increased complexity would be a synonym for the increased certainty of action, as had been the case with many machines. With reference to Professor Hughes' remarks, he might say that he had already quoted Herbert Spencer's words, showing that progress was the differential result of a periodicity of action and reaction, of backward and forward motion. With regard to the rotary engine, he believed that there was now a successful one at work, the Tower spherical engine, which was a marvelous piece of mechanism. He was referring not to the effort to make a rotary engine, but to the way in which those efforts had been made, through ignorance of the principles applicable, one after another having gone on in the same hopeless way, until Mr. Tower had struck out a new line. This had resulted in a motor which though externally it looked very simple was really anything but this, and required elaborate arrangements, and no less than thirty-two figures to completely explain its action and various parts. There was such a thing as degeneration in machines; such a thing as machines made for a higher purpose having for certain reasons to submit to the process of degeneration. The locomotive, vast though its influence on civilization had been, as a type of an efficient motor, and regard simply being had to its maximum efficiency, had certainly degenerated from the condensing engine of Watt. He had not been driving a pet theory, but simply calling attention to what he believed a general law of progress in machines. He had not been quite understood with reference to the line on the curve of application for patents, which showed not only how many never reached completion, but also the immense increase in inventions, and this he had endeavored to show was clearly tending to the absolute necessity for a more scientific classification than at present adopted. A great many men spent hundreds or thousands of pounds for want of knowledge: it was the knowledge of that kind he was advocating; not the knowledge which would prevent them going further, which was simply that little knowledge which was a dangerous thing.

CHIMNEY CONSTRUCTION.

By R. M. BANCROFT and F. J. BANCROFT.

Papers of the Civil and Mechanical Engineers' Society.

Since the reading of the paper on the same subject by Mr. R. M. Bancroft, read in January, 1878, numerous inquiries have been received on the subject from all parts of the United Kingdom and America, owing to the interest and importance of the subject, and in consequence of these inquiries, they had been led to continue their investigations in this branch of architectural and engineering construction.

Chimneys are constructed principally for two purposes,—firstly, to create the necessary draught for the combustion of fuel; secondly, to convey the noxious gases to such a height that they shall be so intermingled with the atmosphere as not to be injurious to the health of the neighborhood.

A chimney-shaft when in work contains a tall column of heated air, which, being lighter than the outside atmosphere, is

forced up by a corresponding column of atmospheric air pressing into the entrance of the furnace; thus a displacement of hot air is constantly being effected, and its place filled by normal air forcing itself through the furnace of the boiler, which in its turn is heated and displaced. The column of atmospheric air and the column of rarefied air in the chimney are somewhat like a pair of scales, or the two ends of a lever of which the boiler is the fulcrum.

Foundations.—In building large chimneys one of the most important points is the construction of the foundation. Very much will depend, of course, upon the nature of the ground. When we are on solid rock, it is only necessary to excavate to such a depth that the heat of the gases will not materially affect the natural stone, and to a depth sufficient to allow the necessary spreading of the base. In many instances, however, chimney stacks have to be built near rivers and on sites where the upper strata are of alluvial clay or made ground, and it is necessary to carry the foundation deep down until a stiff clay, hard sand, or rock bottom is reached. This frequently entails excavation 25 feet or 30 feet deep, or even more, and it is not only requisite that the foundation should be large enough to carry the superincumbent weight, but also that it should be of such an area that it will not allow the base to be forced into the yielding ground. These deep foundations are usually constructed of concrete. In some cases piles are driven in to form the foundation, as, among others, in a brick chimney erected at Boston, and in an iron chimney constructed at Ohio. This is a measure on which the engineers must decide upon the advisability of using it, so as to economize material without risking unequal subsidence, which cannot be too carefully guarded against; and, in fact, it is the practice in the erection of tall stacks to construct the foundation and pedestal, if any, and allow them to stand some considerable time before proceeding with the shaft proper, in order that the work may set and any slight settling take place before a great weight is built upon it. As a remarkable instance of the general settlement of the foundation of a shaft, we may mention a chimney which was built by Mr. Clegg, at Fulham, over a quicksand in which an iron rod sank to a depth of 15 feet with little more than its own weight as pressure. During the erection, the concrete foundation sank bodily 1 foot 4½ inches without cracking the shaft or causing it to deviate from the perpendicular. From this it will naturally follow that in all cases the ground at the foundation should be equally resistant, or unequal settling will take place, as in the disastrous case of the Newlands Mill chimney, Bradford. Some of the pressures exerted upon the foundation are given under the respective descriptions of the chimneys.

Copings and Cornices.—The stone coping or cornice of a chimney will seldom require more to hold it together than two good cramps across each joint; they should be of copper, or double-dovetailed slate dowels. On no account should iron cramps be used, as they will oxidize and burst the stone. Heavy and large caps are often the source of great danger, inconvenience, and expense, as the cap at top in a gale of wind acts upon the shaft as a weight at the end of a long lever. The cap when finished should be a complete whole, or so bound together that the joints cannot open, and be so proportioned that its center of gravity is within the outer circle of the shaft on which it rests, and it should be designed so that the wind striking against it is deflected upwards.

Bond.—In large factory chimney-shafts the longitudinal tenacity which resists any force tending to split the chimney is of more importance than the transverse tenacity, therefore, in these structures, it is advisable to have, say, three or four courses of stretchers to one course of headers. In some circular stacks, a uniform header-bond for the outside courses of brickwork is adopted. This is a practice condemned by some authorities.

Wind Pressure.—It is usual in this country to estimate, as the maximum pressure, 55 lbs. per square foot, but, as in 1868 the pressure of wind at Liverpool was registered at nearly 80 lbs. per square foot, it is advisable to take a higher factor.

If the wind-pressure on a square chimney be taken as	1
that on an hexagonal chimney may be taken as	0.75
that on an octagonal chimney may be taken as	0.65
that on a circular chimney may be taken as	.5

Wrought-Iron Chimneys.—Wrought-iron shafts have found great favor in America and Russia, but in England and the continent generally, as far as we have been able to ascertain, they are an exception. In addition to the wrought-iron shafts detailed in this paper, we have been informed of the following:—Messrs. Witherow & Gordon, of Pittsburgh, Pennsylvania, have since 1876 built upwards of thirty wrought-iron shafts, varying in height from 100 feet to 190 feet, and from 5 feet to 9 feet in diameter. The firm write us that these shafts answer admirably the purpose for which they were built. Mr. L. S. Bent, Superintendent of the Pennsylvania Steel Company, Steelton, Pennsylvania, states that his company have the following eight wrought-iron shafts in use, and have found them both durable any economical:

No. 1,	170 ft.	high,	6 ft. 6 in.	diameter, built '81
No. 1,	165 "		6 ft. 6 in.	" '77
No. 1,	135 "		7 ft. 0 in.	" '80
No. 1,	112 "		6 ft. 0 in.	" '81
No. 4,	110 "		7 ft. 0 in.	" 69'74-5-6

They are lined for 30 feet with 9-inch firebrick, and the remainder of height with 4 inch red brick. The Ravensdale Ironworks Chimney-shaft, Tunstall (Messrs. Robt. Heath & Sons), is a circular wrought-iron shaft, not spread at its base. Its height from ground-line to top is 75 feet; outside measurement at ground surface, diameter 6 feet; ditto at top, diameter 6 feet. Seventy-five wrought-iron plates were used in the construction of this shaft, the thickness being $\frac{1}{4}$ inch. The plates have a lap of $2\frac{1}{4}$ inches, and are riveted together with $\frac{3}{4}$-inch cup-headed rivets. The shaft is lined its entire height with fire-brick. The shaft carries off the fumes from three boilers. The wrought-iron chimney of Messrs. Francis & Co., of the Nine Elms Cement Works, Cliffe Creek, Rochester, was erected in 1878. It was designed by Mr. V. de Michelle, C. E., and constructed by Messrs. Fielding & Platt, Gloucester. The shaft is circular, and parallel throughout, and is constructed of wrought-iron plates. The plates vary in thickness downwards from $\frac{1}{4}$ to $\frac{3}{8}$ inch. Its height from ground-level to top is 160 feet; external diameter throughout, 5 feet; internal diameter throughout, 4 feet 6 inches. It is lined with 3-inch firebrick its entire height. The chimney is stayed against the wind by four $3\frac{3}{4}$-inch steel guy ropes. This chimney was erected over the center one of a row of nine cement kilns, which are all connected to shaft by a wrought-iron horizontal flue 4 feet in diameter. Two additional ones have since been added, and the chimney now carries off the gases from eleven cement kilns. Round the outside of center kiln on the ground level is fixed a cast-iron curb or base-plate. On this base stand four cast-iron standards or supports, having their lower ends butting on to and secured to base-plate. The standards incline inwards until their upper ends meet to support a cast-iron circular chimney-base which forms the top of the center kiln. The wrought iron chimney proper commences from top of this circular cast-iron base, directly over which the 4 feet horizontal flue is connected to shaft. For the construction of this chimney a timber stage was erected at the level of the kiln tops, and upon this stood the rivet fires. Four winches were worked on this stage, and to them were led guy ropes, after passing round blocks at convenient distances. A hydraulic press, with a 4-foot stroke, was then fixed over the center kiln, and the top length of 20 feet, which had previously been riveted-up on the ground, and raised to the stage level, was placed upon the ram. The ram was then pumped up, and the 20-foot length raised a height of 4 feet, the guy-ropes being slackened out to the quired extent, as the 20 foot length gradually rose. A 4-foot ring of plating was then riveted on with $\frac{3}{4}$-inch snap-head rivets and the usual lap, the ram was then again pumped up, and the now 24-foot length raised the necessary height; another ring of plates was then riveted on, and the operation repeated, until the chimney had reached its required altitude. The cost of this chimney was about £1,000, including long wrought-iron flues.

Messrs. Wesenfield & Co.'s Chimney, Chemical Factory, Barmen Prussia.—This has a square brick pedestal and an octagonal brick shaft. Its total height from foundation to top is 345 ft.; height from ground line to top, 331 ft. The pedestal is 20 ft. sq. by 40 ft. high by 7 bricks (equal to 5 ft. 3 in.) thick. The octagonal shaft is 291 ft. high, 17 ft. outside diameter at the base by 5 bricks (equal to 3 ft. 9 in.) thick; 11 ft. outside

diameter at the top by 2 bricks (equal to 1 ft. 6 in.) thick. The shaft diminishes $2\frac{1}{2}$ in. every 10 ft. in height, or 1 in 48. The internal octagonal clearance is 8 ft. throughout. The foundation is on a bed of hard and coarse gravel, and made of large flat quarry stones bedded with "terrass" mortar in the proportions of 1 lime, 1 river sand, and 1 "terrass" (a kind of pozzuolana). The pressure on the lowest part of chimney proper is equal to 21,335 lbs., or $9\frac{1}{2}$ tons, per square ft. The pedestal and shaft were built with bricks and ordinary mortar, composed of 1 of lime to 2 of river sand, prepared every morning by the masons themselves. On rainy days cement mortar was used in the proportion of 1 cement to 2 river sand. The courses of brick were flushed up with cement as construction proceeded. The crown of the shaft was built with cement exclusively. The foundation and pedestal were built in the summer of 1867, and the chimney was successfully completed in October of the same year. According to the original design, it was intended to build to a height of 260 ft., but, as the erection was proceeding in a very satisfactory manner, it was considered safe to increase the height without altering the dimensions of the base. But before doing so, a comparison was made between the pressure on the foundations of this chimney and the pressure on the foundations of a chimney erected at Bochum, Prussia. These were found to be as follows:—

	Lowest part of chimney proper. Press. per sq. ft. lbs.	Press. per sq. in. lbs.
Chimney at Barmen, Prussia..	21,335	149
Chimney at Bochum, Prussia..	18,429	128
Excess of pressure on Barmen chimney foundation.....	2,906	21

The three masons who constructed the chimney daily changed their positions, so as to equalize any unevenness in their respective laying. Every fifty feet a course of brickwork was painted *black* so as to indicate the height of any point of the chimney above ground. The chimney was built from the inside. The materials were hoisted by a steam engine erected temporarily near the place of construction. The frame which supported the upper drum over which the chain worked was moved higher after the completion of every three or four courses, and was at the same time turned horizontally from one side of the octagon to the next one, so as to equalize the pressure of the frame on the masonry. The holes made into the masonry to support the frame were filled up with bricks and mortar immediately after the removal of the frame to a higher level. The chimney, when completed (Oct. 1867), was vertical. In the Spring of 1868, remarkable for storms and long-continued gales, this stalk inclined towards the north-east by the action of the south-west wind, probably aided by the softness of the mortar and the large size and shape of the ornamented chimney crown, which caught the wind and acted as on a long lever. The deflection was considerable at the end of May, and apparently increased. As before mentioned, layers of bricks in the shaft at distances of fifty feet from each other were painted black. The height of these black lines above the pedestal being known, they were, by means of a theodolite, projected on a board which was fixed on the pedestal, and these projections showed that at

251 ft.	high	the chimney	was	out of plumb	45 in.
210	"	"	"	"	30 "
160	"	"	"	"	16 "
110	"	"	"	"	5 "

The pedestal stood perpendicular. As the canting of the shaft was still increasing, immediate action had to be taken. The ordinary method of straightening chimneys was at first resorted to. A hole was made through the whole thickness of the masonry on the side of the chimney which required a lowering, at a distance of 4 ft. above the top of the pedestal; into this hole a saw was passed, and an attempt was made to cut through one-half of the shaft, but owing to the thickness of the wall and the hardness of the bricks, the saw could only be worked from one end, and the effect of sawing after two hours' work was almost *nil*. The hole through the stalk having been made with little trouble, and the difficulty experienced in sawing, led to the idea of removing a course of bricks and replacing it by a thinner one. Before the work was proceeded with, an experiment was made on an old inclined shaft 120 ft. high. This proving successful, it was determined to treat the new chimney in the same way. A layer of bricks was broken out by means of pointed

cast-steel bars, varying from 1 ft. 6 in. to 5 ft. in length. The first division removed was in the middle of one of the octagonal faces. When division 1 was broken out it was replaced by thinner bricks covered with "terrass" mortar. After this, two divisions, one on either side of the first, were broken out and replaced by thinner bricks; then the two divisions on either side of the open space, and so on until one-half of the whole course had been exchanged. Purposely-made flat shovels with long handles were used to lay the bricks, which had to be placed near the inside of the chimney. A side-space of 5 in. was left between the newly-laid bricks and the old ones of the next division, so as to enable the workmen to break out the latter with greater facility. The width of each single division was 2 ft. to 2 ft. 6 in.. The masonry directly above was sufficiently dry not to give way when a course of that width was removed from below it. The replaced bricks were thicker near the points (at 90° distant from the first division cut out), so that the difference was greater in the middle and gradually less towards the extremities. As soon as the slit reached these points the chimney began to move, and by slight oscillations slowly settled down on the new layer of bricks. The time occupied in settling by oscillation at each substituted course varied from 18 to 36 hours, according to the width of the slits, which were different in the various cuts performed. The oscillations were greater the higher the cut. At the highest cut, 100 ft. from the top, the oscillations frightened the masons, and they left the place. The slit became alternately wider and narrower by $\frac{3}{4}$ in.. This seems to prove the elasticity of the structure. Four cuts were made,

1st	4 ft. above	pedestal,	greatest	width
2d	100	"	"	"
3d	140	"	"	"
4th	191	"	"	"

After the completion of this work the chimney continued during several weeks to settle slightly in the direction opposite to its former inclination. This circumstance had to be carefully considered beforehand, or else the slits would have been made too wide, and so have produced an inclination in the opposite direction. A severe storm on the 6th and 7th December, 1868, which overthrew several chimneys in the neighborhood, did not affect this one. The result of the straightening operation described above was quite satisfactory. The heights of the upper cuts were reached as follows: Standing on a platform, the masons made a number of holes into the exterior wall of the chimney, 4 ft. above the platform on which they stood. Into these hole the ends of iron bars were fixed, and boards secured to them so as form another platform. Standing, then, on the latter, they fixed another platform 4 ft. higher, in the same way. Every second platform was removed, so that the remaining ones were 8 ft. apart; they were then joined by ladders for the workmen to ascend. This method of straightening is only practicable when the chimney has a considerable diameter, and when the mortar is sufficiently dry as not to give way under pressure of the bars and platforms.

Chimneys at Duisburg.—In December, 1868, a chimney was straightened at this place by the method just described, but as the diameter was not so great as that at Barmen, and as the mortar was soft, a wooden scaffold was erected round the shaft to reach the upper points which required cutting. The breaking out and replacing of bricks could not be done in divisions wider than 5 in. to 10 in., as the upper masonry, not being dry, would have settled down. When the chimney was straight, a further settling down towards the side of the cuts was prevented by driving iron wedges, covered with mortar, into the slits.

Edinburgh Gas-Works Chimney.—This chimney was designed by Mr. Mark Taylor, engineer to the company. Messrs. Geo. Buchanan, C. E., and Prof. Gordon, of Glasgow, were consulted. The builders were, for the stonework, Mr. James Gowan, of Edinburgh, and for the brickwork, Mr. James Bow, of Pollocksfields, near Glasgow. The pedestal is square, and of stone, surmounted by a circular brick shaft. Its dimensions are:

Stone foundation under ground	6½ ft.
Part of base	6 "
Stone pedestal above	65 "
Brick shaft	264 "
Total height from foundation to top	341½ "
Height from ground line to top,	329 ft.

The foundation stone is 40 ft. 6 in. square, by 6 ft. 6 in. deep. The pressure on the bottom of foundation per square foot is nearly 2½ tons. The stone pedestal is 30 feet square at ground line, and 27 ft. 9 in. square at top. The internal diameter of the pedestal is 22 ft. 6 in. at bottom, and 20 ft. 4 in. at top. This was built during one summer, at the end of which the works were suspended until the following year. The brickwork of the shaft was commenced and finished in the summer following the erection of the pedestal. The following dimensions relate to the outer brick shaft (circular):

Outside diameter at bottom	.....		26 ft. 3 in.
Internal	"	"	..... 20 ft. 5 in.
Outside	"	at top	..... 15 ft.
Internal	"	"	..... 12 ft.

This was built up in five steps, as follows:

1st	section,	35 ft.	high, 3½	bricks,
2d	"	40 ft.	" 3	"
3d	"	48 ft.	" 2½	"
4th	"	58 ft.	" 2	"
5th	"	83 ft.	" 1½	"
		264 ft.	total.	

The greatest pressure on any part of the work comes at the lowest section, where it amounts to about 8 tons 2 cwt. per square foot. The inner brick shaft (circular) is distinct from the outer shaft, and is 90 ft. high, with 13 ft. internal diameter throughout, and was built in four steps, viz.:

1st	section,	14 ft.	high, 35	in. thick,
2d	"	6 ft.	" 30	"
3d	"	30 ft.	" 25	"
4th	"	40 ft.	" 20	"
Total		90 ft.		

The thicknesses include a lining of firebrick 10 in. thick for 20 ft., and 5 in. thick for the remaining 70 ft. The weight of the materials used is about 3,700 tons. The total cost was £4,637. The lightning conductor is a solid copper rod, ⅝ in. diameter. The stones used in the foundation are Cragleith, Humbie, and Hailes, which, before use, were tested by Mr. Buchanan and Mr. James Gowan. The tests were made in the most careful way by crushing cubes of 1 in. square. The following were the results of tests:

Craigleith crushed at	315	tons per	square foot.
Humbie	" 240	"	
Hailes	" 225	"	

A second test of Craigleith showed that before being crushed to powder it sustained a pressure of 440 tons per square foot. The appearance after fracture of the different cubes was that of a pyramid or wedge, and this led Mr. Gowan to assert that if the cubes were enlarged a greater relative increase of strength would be gained, and further that if the pressure were *vertical* to the line of cleavage a greater resistance would be obtained, so that such a stone as Hailes, which is a laminated stone, would increase in strength according to its surface more in proportion than that of a rock-stone such as Craigleith. This led to discussion and further tests, the result being that with a 4 in. cube from Hailes quarry the resistance was equal to 567 tons per square foot. The bricks were supplied by Mr. Livingstone, of Portobello Brickworks, and were tested with the following results:

Description of Specimen.	Length.	Breadth.	Thickness.	Weight.	Crushing weight on each brick.	Crushing weight per sq. foot.
	Ins.	Ins.	Ins.	Lbs.	Tons.	Tons.
Extra size and quality.....	10	5	3	10¼	153	440
" "	9½	4¾	2¾	9 5/16	140	448

Repairs of Chimney-Shafts.—In the *Builder* for January 8th, 1875, there is an interesting account of the repairing of chimney-shafts damaged during the siege of Paris by the fire of the German artillery.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA—RECORD OF SPECIAL BUSINESS MEETING, JUNE 6TH, 1885.—The Secretary presented a communication from Mr. Wm. T. Blunt, secretary of a committee appointed by the Civil Engineers' Club of Cleveland to investigate the relation of army and civil engineers in the Government service, and report a line of action in the premises. The communication requested that a similar committee be appointed by this club.

On motion, the consideration of the subject was postponed for the present.

On behalf of Prof. Louis H. Barnard, M. Dana C. Barber presented an illustrated article upon Stereographic Projection, which being entirely mathematical, does not admit of presentation in abstract.

Mr. Percy T. Osborne presented an illustrated description of the Sand-Bag Embankment to close Little Inlet on Brigantine Beach, N. J., which was constructed by his father, Mr. Richard B. Osborne, C. E.

The closing of this inlet, the width of which was 831 feet, with a rapid current at ebb and flow of tide, never was deemed possible with the very fine sand which was the only material at hand.

The changing character of this shore, under the action of the north-easterly winds, the laws of nature and the results they had in years past produced on this beach, the possibility of making these co-workers in producing like results in a shorter period of time, supplied the only expectation that, with the means possessed, this water way could be obliterated, and a large area of land redeemed from the sea.

By closing this stream for a *short period*, it was expected that the sea would form rapidly what it would require perhaps a century otherwise to accomplish, and that the accretion from the sea would quickly protect and cover up the works of construction, without which it was utterly useless to attempt to build a barrier against the ocean, out of the material available. The expectation has been proved to have been founded on correct principles. The sea has performed its part most fully. The operations of nature's laws have been quickened and the inlet to-day is a thing of the past. The sand was packed in ordinary salt bags, costing 5½ cents a-piece, sewed up and placed in the embankment, at a cost of 66 cents per cubic yard for bags, and 34 cents per cubic yard for filling, sewing and placing, making a total cost per cubic yard of one dollar. The working hours were between half ebb and half flow of tides. The embankment was made from each shore simultaneously, to within a foot of low water, by placing the bags by hand. On these bags, frames, 6 feet in height, 12 feet broad on top, and 8 feet apart, were placed, and connected by planks spiked on the sloping sides. The interior spaces were filled with sand bags, 80,000 of which were used in the construction of the embankment. About 1,050 were placed in a day of 10 hours, 12 of them equaling 1 cubic yard. At low tide the water in the main channel was 13 feet deep when the bank was begun, on June 17th, 1881. On the 5th August following, the embankment was closed and the sea shut out—in 42 working days—and where the deep channel had been, there was then less than 2 feet of water; the deposit of sand from the sea having commenced with the embankment and increased as it progressed. For 9 days after closing, the embankment withstood the heavy seas and south-easterly gales. On Aug. 12th the sea broke over the banks, near the north end, where the water was 2 feet deep. Having some bags on the ground, this breach was closed on the next ebb tide. On the 14th another breach occurred, when there was nothing at hand for its repair, the bags ordered on August 6th not having been supplied for 18 days. When they did arrive the company had discharged the contractor, and the breach had only to be left to itself. It continued to widen up to 16th September, when it was 132 feet, with 16 feet depth of water below the original surface, the old 13 feet channel remained closed, and three bars from the bank seaward had been created. It was expected then that the accretion would still continue, and that finally, in spite of the breech, the closing of the original channel and the alteration of the course of the tide would continue the deposit and finish the undertaking without further efforts. Something was attempted afterwards by one of the company—by driving poles and stretching light wires along them—but these petite attempts conduced in nowise to the ultimate result. The increased action of the sea finally obliterated the inlet, and covered the whole locality, thus proving that nature had fully performed what had been expected of her—70 acres seaward and 30 acres inside were reclaimed.

JUNE 20TH, 1885.—The Secretary presented, from Prof. J. A. L. Waddell, a communication proposing that the Club organize a system of Review of Engineering Literature, and suggesting methods therefor.

The Secretary presented, for Mr. James Beatty, Jr., a paper upon the Relative Costs of Fluid and Solid Fuels. After giving the relative advantages in economy of labor in use, reduction of weight and bulk, ease of manipulation of fire, perfection of combustion, and cleanliness, the principal substances, experiments and processes are noted.

Notes and tables are given as to the compositions of different fuels, their heat units and evaporative capacities, efficiencies in furnace, prices per unit, and lbs. of fuel for $1.00 and lbs. of water evaporated from 212° F. for $1.00, in various localities.

The paper concludes with the following table, of which the author says: "These figures are very much against the fluid fuels, but there may be circumstances in which the benefits to be derived from their use will exceed the additional cost. It is difficult to make a comparison without considering particular cases, but for intermittent heating, petroleum would probably be more economical, though for a steady fire, coal holds its own."

RELATIVE COSTS OF FLUID AND SOLID FUELS.

	Anthracite.	Bituminous.	Petroleum.	Coal Gas.	Generator Gas.	Water Gas.
New York.....	1.00	1.08	1.71	14.92	22.90	8.70
Chicago.....	1.00	.71	1.50	8.72	18.30	7.00
New Orleans...	1.00	.59	1.56	17 90	15 30	5 80
San Francisco.	1.00	.64	1.50	8.75	9.40	3.50
London.....	1.00	.61	2.65	7.16	17.70	6.30
Port Natal	1.00	.90	1 21			
Sydney.....	1.00	.34	1 39			
Valparaiso.....	1.00	.44	1.03			

Prof. L. M. Haupt announced, by title, a paper upon the Repairs to the Conduit of the Philadelphia Traction Company, which will probably be ready for publication during the summer.

The Secretary presented, for Mr. C. W. Buchholz, a Memorial of the late William Lorenz, reviewing his studies, his early experience, his career on the Philadelphia and Reading Railroad from topographer to Chief Engineer, his great scientific and practical ability, and last, but far from least, the extraordinary completeness of his manhood.

ENGINEERING NOTES.

SUMMARY OF REPORT ON PRESERVATION OF TIMBER TO AMERICAN SOCIETY OF ENGINEERS.—After a brief statement of the labors of the Committee and of the evident necessity for the introduction of preserving processes on account of rapidly diminishing supplies of timber, a short history of the progress of the art is given, showing three principal methods of working, viz.:

1. Steeping.
2. Vital suction or hydraulic pressure.
3. Treatment in close vessels by steaming, vacuum, pressure, &c

The experience in the United States is given in five tables, comprising the results more or less conclusive of 142 authenticated trials or experiments. In each case these are referred to at more or less length in the text, sufficiently to give the reasons for success or failure, and the lesson taught. The five heads corresponding to the tables are:

1. Kyanizing, or use of corrosive sublimate.
2. Burnettizing, or use of chloride of zinc.
3. Creosoting, or use of creosote oil,
4. Boucherie, or use of sulphate of copper.
5. Miscellaneous, or use of various substances.

Of the first, *Kyanizing*, it is stated that an absorption of four or five pounds of corrosive sublimate per thousand feet, b m, is considered sufficient, and it would now cost about $6.00 per 1,000 feet, b. m. It is not recommended except in situations where the air can circulate freely about the wood, as in bridges and trestles, but in very damp locations (as for ties when in wet soil and pavements), its success is doubtful. Its cost when first used led to cheating, which for a time brought discredit upon it.

Burnettizing the committee do not consider the best adapted to use where the timber is exposed to the washing action of water (as this removes the preservative); but, on account of its cheapness, it is probably to be preferred at the present time to any other process for the preservation ef railroad ties. The Wellhouse, Thilmany and other modifications of the process aim at making the chloride insoluble, but are yet on trial. This process has been largely and successfully introduced in Germany. Experience shows the life of soft wood ties to be doubled and trebled by its use. Its cost in this country is about $5 per 1,000 feet, b. m., or 20 to 25 cents per tie, and for the latter purpose the committee particularly recommend it. The work must be well done; but some of the failures were from doing it *too* well, that is, from using solutions of too great strength, thus making the timber brittle.

A solution of 2 per cent., by weight, of chloride of zinc in water is recommended.

Creosoting, or the injection of timber with hot creosote oil in a cylinder under pressure, is considered to be the very best process which has been fully tested, where *expense* is not considered. It is as yet the only one known which is sure to prevent the destructive attacks of the teredo or other marine animals, and to give absolute protection against decay in very wet situations. It is a somewhat expensive process, requiring for protection against the teredo from 10 to 20 pounds per cubic foot of timber, and costing from $12 to $20 per 1,000 feet, b.m. For resisting decay alone a cost of $10 to $14 is sufficient.

The *Boucherie* process, in which green timber is impregnated with sulphate of copper either by *vital suction*, *hydraulic pressure* or a *vacuum*, when well done, using a solution of 1 pound of sulphate to 100 of water, has proved fairly successful.

Under the head of "miscellaneous," are classed 41 experiments with almost as many substances, sulphate and pyrolignite of iron, lime, resin oil, tar, &c., but with as yet no commercial success.

The general principles laid down are, to select the process with reference to the subsequent exposure. Use *open-grained*, *porous* timber, for that reason in *general* the cheaper woods.

Extract the sap and water to make room for the material to be injected, natural seasoning, except for the Boucherie process, being very desirable. Steaming takes the place of seasoning.

Use enough of the antiseptic to insure a good result, and then let the timber dry before using, as its durability will thus be increased. Do not hasten the work if it is to be well done. Protect ties or timber in the track as far as may be from water by drainage.

Contract only with reliable parties of establish reputation, under a skilled inspector, who must be in constant attendance when the magnitude of the order warrants.

There is at the close a discussion of the question, Will any preserving process pay? This is answered in the affirmative. The chairman of the committee gives a careful estimate in one of the appendices in an actual case in this country; another general estimate is given based on European experience, and three other separate appendices give different methods of examining the question of economy and comparing values.

Other appendices (to the number of twenty in all) treat of the general question of destruction and conservation of forests, and give reports of the personal experience of a number of engineers, with methods pursued, apparatus used, &c.

AMOUNT OF WATER REQUIRED FOR IRRIGATION IN SALT LAKE CITY.—The amount of water, which Salt Lake City requires for irrigation during the period of about 120 days, from

the middle of May to the middle of September, is so enormous, that the amounts required for domestic and other purposes, sink into insignificance by comparison. Fast becoming a city, filled with lawns and shrubbery, in place of gardens and ordinary crops, with abnormally wide streets, the requirements are simply immense. Long experience has demonstrated that watering in our climate for city lots, should be as often, as at least once a week, and such is the custom here. During the "season," from 17 to 20 waterings are had; and we find from the tables of rain fall, that only 3.31 inches of rain can be depended on during this period. Experience has also demonstrated, that the *best results* are obtained, when, at each watering, as much water is used as would be equal to covering the ground one inch deep. At *least*, this amount is generally required.

This, therefore, means, that, during the "season," from 20 to 23 inches are flowed over the land, the rainfall being counted in; and practically amounts to the same as though that many inches of rain had fallen, between the middle of May and middle of September. To those not familiar with the needs of irrigation, this seems an unusually large allowance, and very few appreciate how large an amount of moisture they put on an acre of ground, when they cover it an inch deep. It means .63 gals., or $5\frac{1}{4}$ lbs. per sq. ft., or 113 tons per acre at each watering, or 2,260 tons of water in a season. Yet, large as this looks, it is not as great as the original founders of the city deemed necessary to provide.

In a conversation had with Mr. Orson Pratt, some fifteen or sixteen years ago, on the subject of amount of water required for irrigation here, that gentleman said to the writer "It was our intention that one cubic foot of water per second should suffice for 100 acres of land for about as many days, and at the outset that or more perhaps was used: since we have got the ground saturated our crops don't probably require, in ordinary seasons, more than half that."

This one cubic foot per second of water duty, allows nearly 24 inches for a season of 100 days; but gardens, lawns, etc., require water during at least 120 days. At each watering we find required not less than 3,630 cubic feet, or 27,225 gallons per acre. During parts of July and August, the least flow of City Creek is given as being 7,200,000 gallons, or 960,000 cubic feet per day, sufficient for 1850 acres during the "season." The total number of acres outside of the 1st, 10th and 11th Wards, lying above City Canal level, including the cemeteries, is 812, of which 295 are already supplied. Should the balance of this 812 acres be also watered from City Creek it would divert 2,010,757 gallons of that water, now flowing into the lower wards. The result being that *all* the water from City Creek not required for lands above canal level, or 4,041,901 gallons could pass through the pipes; instead of the bulk of it as now, going through the ditches. Water through the pipes means an income therefrom, and at 20 gallons per head, this 4,000,000 gallons gives a supply for 200,000. people. By storing one-fourth of the flow of City Creek this four millions can be more than doubled.

Thus using City Creek water for the areas *above* City Canal level, leaves 2,840 acres in the city *below* its level. Should this canal be drawn upon for its full capacity, it would admit of flooding this entire area of 2,840 acres, $1\frac{5}{8}$ inches deep every day, or $11\frac{3}{8}$ inches at each watering, or 16 feet deep during the season.

It follows, therefore, that the canal, for the *necessary irrigation only*, of the lands within city limits below its level, need furnish but 11,045,571 gallons daily Two-thirds of the whole area of the city would thus seem to be pretty well provided with water.

This apportionment of the waters, if made, would only be carrying out in detail, the ideas suggested by Mr Ellerbeck last summer, or like that now made in alloting the canal water in lieu of Emigration Creek in the 1st, 10th and 11th Wards, and will give to those making the exchange, more water, should it be required, than they could ever secure from City Creek alone.

It has been suggested, that owing to its leaky condition, the canal cannot be made *at present* to flow to its capacity. Neither will it at present be required to. The amount proposed to be taken from City Creek, for the entire 517 acres unsupplied, including Cemeteries, only diverts 2,010,757 gallons, from that creek, and not that amount until the whole of these 517 acres shall have come under irrigation. As a matter of fact *at present* and with full supply given, to the lands of the living and to the Cemetery, less than 1,500,000 gallons per day will be diverted for several years, leaving some 20),500,000 gallons for pipe supply, more than now flows through them.

Repairs would certainly remedy the leakage of the canal, and repairs like repentance are always in order, and an extra four millions of flow would require but five inches more depth. Whatever may be said about the faulty construction of this great waterway or the damage from muskrats, yearly, the wisdom displayed in its adoption was of the highest order. Nor has it been built any too soon to meet our rapidly increasing wants. The waters of Utah Lake, which it brings us, for irrigation and manufacturing purposes, are superior in quality to those from all other sources. We are, however, frequently told that the construction of a canal at all was a terrible mistake, that a pipe should have been laid to prevent any chance for damage to lands along its route, etc. Well! a pipe, or its practicable equivalent, a masonry conduit, would be a good thing to have, but to bring the same amount of water from the same starting point on the Jordan, would have required that conduit to be eleven (11) feet in diameter, or if iron pipes were used, 14 of them 3 feet in diameter, would have been required, and carried the cost away up into the imposing millions. Surely the $225,000 the canal has cost was a judicious expenditure.

With a city like Salt Lake, which has no large manufactories a supply of twenty gallons per head, exclusive of hose service, is generally conceded by all hydraulicians ample for domestic purposes. This means 7,300 gallons

per annum to an individual. Now, an acre of land requiring irrigation during the same period, though distributed generally during 120 days, requires not less than 490,000 gallons, or nearly 70 times as much. During the 120 days, however, the acre consumes 204 times as much as the individual. Following out the calculation we find that the water absolutely required for our irrigation, with no allowance for entailed or other waste, would suffice for a population of 852,000 people. I gave these figures to show the cause which necessitates such immense volumes of water. The probabilities are, that during the dry season, 50,000,000 or more gallons daily will be used and rightfully wasted. By rightful waste I mean that quantity of water left to flow in our streets not only for irrigation therein, but that which cannot well be controlled, as also that quantity, which so flowing will always be an important factor from a hygienic point of view.*

In all the foregoing estimates the quantities given are for a supply to the *entire* acreage of the city; while the least capacity of the streams have been taken as the basis from which such supply is to be had. This is not entirely a just way of estimating, since, it is fairly presumable that whenever required in the future, one-fourth of the flow of both City and Emigration Creeks could be stored and utilized.

As will also be noticed no deduction has been made for buildings, the whole area having been computed as requiring irrigation. The requirements of the streets, will, however, quite offset this amount, and it is sincerely to be hoped that no diminution of the flow along them will ever be required, and below the canal there would seem to be no excuse for any such diminution.

IRON AND STEEL NOTES.

Magnetization of Iron, Nickel, and Steel.—Mr. Shellford Bidwell has communicated a paper to the Royal Society on the changes produced by magnetization in the lengths of rods of iron, steel, and nickel The most novel result of these observations is the fact that if the magnetization of iron rods be carried beyond a certain critical point, the consequent elongation, instead of remaining stationary at a maximum, becomes diminished, the diminution increasing with the magnetizing force. If the force is sufficiently increased, a point is arrived at where the original length of the rod is totally unaffected by magnetization; and if the magnetization be carried still further, the original length of the rod will be reduced. It also appeared from Mr. Bidwell's researches, that the position of the critical point in steel depends in a very remarkable manner on the hardness or temper of the metal. Considerable light is thus thrown on the anomalous results obtained by Joule and Mayer. His experiments also disclosed reasons for believing that the value of the critical magnetizing force in a thin iron rod is greatly reduced by stretching. This explains the fact that Joule obtained opposite effects with stretched and unstretched wires. It is known that the length of a nickel bar is diminished by magnetization, and Mr. Bidwell shows that it continues to retract with magnetizing forces far exceeding those which produce the maximum elongation in iron. The greatest observed retraction in the case of nickel was more than three times the maximum observed elongation of iron, and the limit was not reached in the experiments. A nickel wire stretched by a weight undergoes retraction when magnetized. The critical value of the magnetizing force for a steel rod diminishes with increasing hardness up to a certain point corresponding to a yellow temper; after which it increases, and with very hard steel becomes very high. There is, therefore, a critical degree of hardness for which the critical magnetizing force is a minimum. In steel of a yellow temper the value of the critical magnetizing force is lower than in steel which is either softer or harder. A temporary elongation once produced in soft steel may be maintained by a magnetizing force which is itself too small to originate any perceptible elongation.

Safety of Iron Pillars in Cases of Fire.—We stated sometime since that owing to the upper stories of buildings in Berlin falling in during a fire, by the giving way of cast-iron pillars, the Prussian police authorities had issued an edict forbidding the use of cast-iron pillars in any inhabited building, but permitting the use of wrought-iron pillars. Cast-iron may only be used provided that each pillar is surrounded by a fixed casing of sheet iron, in such a manner that there is a good air-space between the two. This edict has provoked much criticism and opposition, and several authorities have reasoned against it, as well as made experiments to disprove the assumption on which it is based. Prof. Bauschinger of Munich, recently made a long series of actual trials with pillars of both cast and wrought-iron. He loaded them with the weights that they are usually allowed to bear in buildings, and heated them first to 300 deg. Cent., then to 600 deg. Cent., and finally to a red heat, and let a stream of cold water play on them, exactly as would be the case in a fire being extinguished by fire engines. The cast-iron pillars were much damaged and cracked by this treatment, but continued to carry their loads quite safely, while those of wrought-iron were much bent before redness was reached, and so twisted when cold water was squirted on them that they could not carry their loads. The conclusion is that cast-iron is really far safer for buildings than wrought. Pillars of other materials were also experimented with, viz., natural stone, brick, and concrete. The latter stood the test best, resisting a fire of three hours' duration. Also pillars of ordinary brick stood very well, but granite, sandstone, and other natural stones did not show as much resistance. If the obnoxious edict of the Berlin police has done no other good, it seems at least to have set a good many people to work on this important subject.

* The streets of Salt Lake City are 132 feet wide, and it is the intention to keep a continuous flow in the side ditches. With the exception of about six weeks in winter this flow of water is kept up. There is not a sewer in the city.

RAILWAY NOTES.

It is said that the construction of a ship railway to connect the Bay of Fundy with the Gulf of St. Lawrence has been finally decided on. Ships of 1,000 tons and under will thus be able to reach St. John from Montreal, Quebec and other ports on the St. Lawrence, without having to encircle the dangerous Nova Scotian coast, a saving of 600 miles. The ship railway, which is to be seventeen miles long, will, it is expected, be supported by a subsidy of £60,000 per year for twenty years from the Canadian Government.

There is still running on the Western and Atlantic Road, in Georgia, hauling a passenger train, the old locomotive General, which —the *Railroad Gazette* says—was the pursued party in one of the most exciting chases on record. The locomotive was carried off by a small party of Federal scouts during the war, while the engineer and firemen were at dinner, and the train was stopping at Big Shanty. The pursuit was kept up for over 100 miles before the engine was finally recaptured, and she was only abandoned when entirely out of fuel and water, and the journal bearings had been almost entirely melted out, the supply of oil having also run out. In the chase, this General and the pursuing engine probably made the fastest time ever run on a southern road, although all parties were too much engaged in the business on hand to keep any record of the actual speed.

ORDNANCE AND NAVAL.

An addition to the German navy was made on the 18th of May, by the launch, at Dantzic, of the fast cruiser corvette, Arcona, which took place in the presence of General von Caprivi—the chief of the German Admiralty—Admiral Jachmann naming the vessel. The Arcona is a sister ship to the Alexandrine, launched in February last at Kiel, and is of the following dimensions: Length between perpendiculars, 72 meters (237 ft.); breadth of beam, 13 meters (42 ft.); displacement, 2370 tons. She is built of iron and steel throughout, and has a double planking of teak, sheathed with copper. Her draught of water when completely fitted up and fully armed will be 4.60 meters (somewhat over 15 ft.) forward and 5 meters (16 ft. 6 in.) aft. The vessel is divided into eight watertight compartments by cross bulkheads, the two largest ones containing engines and boilers. She will have two compound engines, working independent of each other, placed side by side in the direction of the keel, and developing together 2,400 horse-power. Steam will be supplied by eight cylindrical boilers, four to each engine, placed into two separate boiler rooms. The estimated speed of the Arcona is between 14 and 15 knots (16 to 17 miles) an hour. She will be armed with twelve 15 centimeter (5.85 in.) and two 8.7 centimeter (3.39 in.) guns, one light gun, and four Hotchkiss guns. She will also be fitted with a launching apparatus for Whitehead torpedoes.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

Minutes of the Proceedings of the Institution of Civil Engineers.

Paper No. 1983.—Modern Practice in Construction of Steam Boilers. By David Salmond Smart.

No. 2024.—Comparison of British and Metric Measures for Engineering Purposes. By Arthur Hamilton Smythe, B. A.

No. 2047.—Maximum Flood-Discharge from Catchment Areas. By James Craig, M. Inst. C. E.

No. 2051.—Experiments on Friction of Disks Rotated in Fluid. By William Cawthorne Unwin, M. Inst., C. E.

No. 2056.—Method of Removing Rock under Water. By Charles James, Assoc. M. Inst. C. E.

No. 2065.—Cost of Dredging at Calais and Boulogne. By F. Guillain.

No. 2073.—Guns as Thermodynamic Machines. By James Atkinson Longvige, M. Inst. C. E.

No. 2074.—Standard Engine Shed. By Francis William Webb, M. Inst. C. E.

No. 2079.—Brauer's Dynamometric Brake. By H. Walthier Messnier.

No 181.—Students' Paper—Trigonometrical Surveying.

No. 185.—Students' Paper—Secondary Batteries.

No. 188.—Students' Paper—Gauging Flowing Water.

Professional Papers of the Signal Service. No. XVI. Tornado Studies for 1884. By John P. Finlay. Washington: Signal Office.

Monographs of the United States Geological Survey. Vol. VI. The Older Mesozoic Flora of Virginia. By William Morris Fontaine. Washington: Government Printing Office.

Monthly Weather Review for April, 1885. Washington: Signal Office.

Report on Water Supply for Salt Lake City. By Charles L Stevenson.

A Manual of the Theory and Practice of Topographical Surveying. By J. B. Robinson, C.E. New York: John Wiley & Sons.

This treatise deals with the use of the transit and stadia.

The writer explains in the preface the plan of the work as follows:

"The writer has three objects in view in the preparation of this work, viz.:

"*First*—To prepare a manual that could profitably be put into the hands of students in surveying, and then be of further use to them in the field.

"*Second*—To so clearly and minutely explain the theory and methods of field work, that an engineer in practice could, without other instruction, prepare his instruments, and do the work in good shape.

"*Third*—To furnish such means of reducing the field notes, with such methods of plotting as have resulted from many years' experience of many engineers engaged in the business."

The Winslow tables, with which our readers are doubtless familiar, are appended to the text.

AN INTRODUCTION TO PRACTICAL ORGANIC ANALYSIS. By GEORGE E. R. ELLIS. London: Longmans, Green & Co.

This is a convenient little manual for chemical students. It is particularly good in specifying the characteristics of the leading organic acids and alkaloids, and in the directions for general examination.

The work is well printed, and is made to have the appearance of being illustrated by the ingenious process of repeating a simple diagram three or four times. This is a harmless practice when no illustrations are called for nor referred to.

THE ELEMENTS OF RAILROADING. By CHARLES PAINE. New York: Railroad Gazette.

This is a series of essays reprinted from the *Railroad Gazette*. How extensive the variety of topics presented may be seen by the following list of chapter headings: Surveying and Construction, Real Estate and Records, Drainage, Main Track, Trackmen and Sidings, Stations, Shops and Engine Houses, Telegraph Lines and Fences, Locomotives, Cars, The Movement of Freight, The Movement of Passengers, Employes.

Of course each of these important subjects is treated only in a cursory manner, as the thirteen chapters cover only 154 small pages. Many good suggestions are afforded young engineers in the way of caution about common errors in railroad construction and maintenance.

THE TECHNOLOGY OF BACTERIA. By CHAS. S. DOLLEY, M. D. Boston: S. E. Cassino & Co.

This work is designed to stimulate students to microscopical research. It is divided into three parts. Part I. is devoted to the directions for obtaining organisms from various sources and their preparation for the microscope. Experimental culture of Bacteria receives a fair share of attention in this part.

Part II. deals with the special methods employed by Pasteur, Koch, and many others, to propagate Bacteria of particular maladies.

Part III. describes the use of the preservative and coloring fluids used in connection with the preparation of minute organisms for the microscope.

The absence of illustrations will render a microscope manual a necessity to a beginner.

FRICTION AND LOST WORK IN MACHINERY AND MILL WORK. By ROBT. H. THURSTON.

The author is so well known that we need not devote space to showing that the book is of a highly practical and thoroughly scientific character.

Nothing more than a statement of the range of topics seems called for.

Chapter I. treats of the Theory of Machinery and deals with precise definitions of scientific terms.

Chapter II. on Nature, Laws and Theory of Friction, is probably the most important in the book, as the author has made this a special subject of research.

Chapters III., IV. and V. treat of Lubricants, their application, and the chemical and physical tests to which they should be subjected before application in important cases.

Chapters VI and VII. deal with Experiments, Testing Machines and the Coefficients of Friction.

Chapter VIII. treats of the financial aspect of the question, and exhibits calculations of cost of oil, loss of useful effect, etc.

It is a worthy addition to the list of useful books by this author.

MISCELLANEOUS.

THE SOUTH FORELAND LIGHTHOUSE EXPERIMENTS.—The long series of experiments made during last summer and autumn at the South Foreland to test the respective merits of oil, gas, and electricity for lighthouse illumination, have been brought to close, and the reports will now be drafted and published. Pending their appearance, which will necessitate some delay owing to the voluminous character of the observations, we may mention that the evidence is in favor of the electric light on the whole, because of its far-penetrative power. While the rays of oil and gas lights were lost sight of at a distance of eight miles, the electric light could be seen for fourteen miles; and with gas or oil at its maximum power, and visible for 10 miles, the electric light could be seen for 14½ miles. Although the arc is very much reduced in fogs, it still appears to be visible farther than gas and oil. By direct testimony of observers, the electric light became visible in dense fogs at a distance of 1500 feet to 1900 feet, whereas gas and oil were only discerned at distances of from 1250 feet to 1500 feet. This is an important point, because it was thought gas and oil might have the advantage over electricity in dense fogs There is no doubt that fog does quench the direct rays of the arc light in a remarkable manner; but how much this would diminish its efficacy in a practical sense was not well known hitherto. Probably the white haze surrounding the lamp is detected for a considerable distance, although the arc itself in a fog has lost its brilliance. So long as this haze is seen, mariners will learn to distinguish it as the lighthouse. The heating due to the use of gas was found to be very considerable. With the original 88-jet burners the temperature rose to 200 deg. Fahr. but the subsequent use of 108-jet burners brought it to 300 deg. and 350 deg. Fahr. These burners gave an illuminating power of 2400 candles. The electric arc lamps used gave a light of 12,000 candles each. Four of the gas burners were superposed in a quadriform arrangement, and three arc lights were sometimes used. For the oil lights the Trinity House six-wick burners were employed, each giving a light of 800 candles. We may add that although the experimental trials are for the present over, the photometric observatory and testing towers will be allowed to remain for further use and testing purposes. This is a sensible decision, since whatever the results of the trials at present, they cannot be regarded as conclusive while the subject of illumination is engaging so much attention.